Assessment of Brazil's Research Literature

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List of Acronyms and Abbreviations

EC: Engineering Index (EI) Compendex
FINEP: Financing Agency for Studies and Projects
MCT: Ministry of Science and Technology
OECD: Organisation for Economic Co-operation and Development
PINTEC: Pesquisa Industrial de Inovação Tecnológica
S&T: Science and Technology
SCI: Science Citation Index
SSCI: Social Science Citation Index
USP: University of Sao Paulo

To facilitate user access to this information, we provide:

1) 1-page Executive Summary
2) 21-page Summary
3) Main Report, and
4) interactive access opportunities.

Executive Summary: Assessment of Brazil's Research Literature

This report analyzes tens of thousands of research papers by Brazilian authors drawn from global databases [Science Citation Index ("**SCI**") and Social Science Citation Index ("**SSCI**"), and the EI Compendex ("**EC**")]. The resulting profiles indicate Brazilian R&D strengths. These analyses show trends in Brazilian research and point to the leading research organizations.

The Ministry of Science and Technology ("**MCT**") has primary responsibility for R&D and promotion of innovation. It oversees a complex organizational framework, and most Brazilian states have Science & Technology agencies, most notably, Sao Paulo. MCT currently strategically targets seven R&D domains: pharmaceutical, information & communication technologies, biomass & energy, capital goods, aerospace, biotechnology, and nanotechnology.

In 2004, 20% of R&D was performed by the government, 40% by universities, and the remaining 40% by firms (private and public – e.g., Petrobras). Government funded 58% of that R&D activity; firms funded 40% (private and public); and universities, 2%. Brazil's public and private R&D accounts for approximately 1% of GDP. The leading industrial R&D sectors are transportation (37%), chemicals (12%), and energy (12%). Universities employ some 90% of the 48,000 PhD scientists. Leading research universities are mainly public, led by the University of Sao Paulo. Brazil's relatively strong R&D effort has not translated to strong rates of innovation. Interaction among the public, academic, and private sectors lags.

Brazil actively publishes research results. Its profile in these S&T databases is substantial – some 18000 articles in 2006 in SCI/SSCI and some 6000 in EC. The trend in each shows strong growth – tripling from 1995 to 2005 in SCI/SSCI and increasing nearly 6-fold in EC. That is faster growth than by Argentina, but slower than by South Korea – two benchmarks. Brazilian research shows relatively strongly in the **life and biomedical domains**, compared to countries such as India and China.

The leading SCI/SSCI journals in which Brazilians publish are mainly Brazilian, and these tend to have lower impact factors (their papers are cited less by others). Brazilian publications show an upward trend in weighted impact factor from 1985 to 2005, roughly comparable to the rate of increases seen for comparison countries.

Brazilian researchers are attuned to the global scientific enterprise. They most cite leading international journals. International collaboration is extensive – e.g., for 30% of Brazilian articles indexed by SCI/SSCI for 2006, led by the USA as collaborator on about 12%. Dentistry, Parasitology, Agriculture, and Tropical Medicine show notable absolute differences in publication favoring Brazil over the USA. EC comparisons show Brazilian strengths in chemistry and several industrially oriented R&D domains.

We apply text clustering to obtain "self-organizing tables of contents." These offer multiple perspectives on Brazilian research concentrations. Companion maps show linkages among topics and among research organizations. We also facilitate *interactive access* into these data to help one answer specific "who is doing what?" questions. This study also explored identifying *military-relevant*, Brazilian R&D from open literature compilations.

Main Report: Assessment of Brazil's Research Literature

1. Objectives

This report identifies the science and technology (S&T) core competencies of Brazil. After a brief background on Brazil's R&D infrastructure and funding, it analyzes Brazilian research publications. Publication information is compiled from the ISI Web of Science and EI Compendex databases. Selective data from other countries are included for contextual comparisons. The report is modeled on prior ONR country studies. It also explores additional metrics and presentations to enrich the model and facilitate user access to the S&T intelligence they seek. Additional interactive capabilities are offered for users who wish to probe "who is doing what" for topics of particular interest.

2. Background

Research and development is becoming notably more global. No longer can one focus only on the U.S., Western Europe, and Japan to tap research knowledge generation. In particular, the BRICs (Brazil, Russia, India and China) represent emerging economies with substantial industrial momentum and innovation potential (Hane, 2008). No longer can the BRICs be dismissed as low-cost manufacturers; they are now notable R&D knowledge producers as well. In particular, many tabulations of scientific publication -- in the physical sciences generally and in frontier domains such as nanotechnology in particular -- find China pressing the U.S. for global leadership (Youtie et al., 2008; Porter et al. 2009; Kostoff 2008; Kostoff in press; Kostoff, Barth, and Lau 2008).

Why study Brazil? Brazil warrants attention as a large and rapidly emerging economy (OECD, 2008). It shows inclinations to reconcile its natural resources economic model with a knowledge economy (Bound, 2008). Brazil stands out as the leading Latin American economy, and a country with substantial R&D collaboration with the U.S. Mapping Brazil's scientific output helps to identify its strengths, and potential avenues for future collaborations with U.S. R&D players.

This "country study" analyzes substantial samples of research papers by Brazilian authors drawn from two global databases (Web of Science and the EI Compendex). The resulting profiles aid in understanding Brazilian R&D strengths. This paper highlights the approach and findings of a substantial report to ONR [Brazil DTIC TR ADA# - to be added].

ONR has completed country studies for Mexico, Finland, China, and India.[1] [2] [3] [4] Many are also available as articles (Kostoff et al. 2005; Kostoff et al. 2007a; 2007b; 2007c). Concurrently with this study of Brazil, colleagues updated the India study and others profiled South Korea. These reports aim to provide ONR and other US Government agencies with leads to facilitate potential collaboration. Knowledge of external R&D activities is a necessary foundation to identify mutual interests to purse research, development, and innovation. Such collaboration is increasingly important (c.f., Chesbrough 2006).

The prior country studies discuss the literature on *core competencies*, *country technology assessment*, and *text mining* vis-à-vis profiling R&D (c.f., Kostoff et al. 2006a & 2006b). In essence, analyzing the collective body of work by a country's researchers can be accomplished by text mining results of searches in the global Science and Technology ("**S&T**") databases. The synergy of combining text mining with expert opinion is superior to relying solely on either

The rationale for these bibliometric analyses to profile a country's R&D capabilities has been explored in the prior country studies. For the sake of brevity, we only highlight the key concepts. We refer readers interested in fuller discussion and treatment of the literature on the notions of core competencies, country technology assessment, and text mining to the prior country studies (especially India and Finland).

"Core competencies" here refer to a nation's strategic capabilities in S&T, as the foundation for technological innovation. Intelligence concerning country core competencies can help:

1. Prioritize areas for joint R&D ventures
2. Identify the right researchers with whom to establish such ventures
3. Assess a country's military potential
4. Anticipate emerging capabilities of scientific, commercial, or military importance (and avoiding surprise).

Developing sound assessment of a large country's S&T capabilities poses challenges. Traditional reliance on human expertise is costly, likely to miss emerging areas, and difficult to mobilize. We thus turn to "text mining" of literature compilations. This has its own limitations:

1. Not all R&D results in open publication
2. Web of Science (a key database used here) covers journal articles, not conference papers [EI Compendex does cover engineering-oriented conference papers]
3. International database coverage favors English (so Brazilian articles in Portuguese are less apt to be included).

Such bibliometric (activity analyses) and text analyses also provide unique strengths:

1. Global reach – these publicly available (not free) data resources cover S&T papers in thousands of prominent journals

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[1] www.onr.navy.mil/sci_tech/33/332/docs/MEX_TECH_ASSESS_6.pdf
[2] www.onr.navy.mil/sci_tech/33/332/docs/FINLAND_DTIC_REPORT_8.pdf
[3] www.onr.navy.mil/sci_tech/33/332/docs/060307_chinese_sci_tech.pdf
[4] www.fas.org/irp/world/india/research.pdf

2. Fast access – the databases are searchable from one's desktop, providing instant access to tens of millions of papers
3. Reproducible – others can verify findings
4. Efficient – through use of text mining software, data cleaning and analyses become practical; furthermore, repetitive procedures can be programmed (e.g., Visual Basic scripting) to semi-automate many of the steps (Porter and Cunningham, 2005)
5. Effective – new insights are possible through research profiling of entire bodies of literature (Borner et al., 2003 & 2004; Porter et al., 2002), and literature-based discovery can enhance our research endeavors (Dr. Kostoff has several exciting initiatives underway[5] [6] -- Kostoff et al., 2008).

Technology assessments based on the global S&T literature offer practical intelligence value. Prominent among those developing and applying text mining tools to derive such intelligence is Dr. Kostoff's group at ONR. They have generated a multitude of studies, typically keying on a particular technology [c.f., some 70 reports available on the web[7]].

Text-mining country studies pose special challenges. Various approaches are possible. We also note that such country assessments nicely complement focused, expert opinion methods. For instance, site visitation planning can build upon identification of key national S&T areas, and leading research groups associated with each.

3. Brazil's R&D Establishment and Funding[8]

3.1 Brazil's Science & Technology Establishment

Brazil is a large country – land area of 8.5 million km^2 and 190 million people, compared to the USA at 9.2 million km^2 (land area) and 301 million people.[9] Brazil has the largest Science and Technology (S&T) system in Latin America. In order to manage and control its S&T organization, Brazil relies on a complex system of institutions, largely under the umbrella of the Ministry of Science and Technology (MCT) (Figure 1).

Figure 1 - Science & Technology Establishment Structure

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5 For a novel, hybrid discovery approach, see: www.onr.navy.mil/sci_tech/33/332/docs/managing_innov.doc
6 For a listing of earlier discovery work: http://kiwi.uchicago.edu/references.txt
7 http://www.onr.navy.mil/sci_tech/33/332/techno_watch_publications_textmine.asp
8 Section prepared by Elena Harari, drawing upon multiple sources.
9 Estimates as of June, 2007 from: www.cia.gov/library/publications/the-world-factbook/

Source: Ministry of Science & Technology – www.mct.gov.br (simplified organizational chart)

Created in 1985, the MCT is responsible for designing and implementing national S&T policy, focusing on planning, coordinating, and overseeing R&D activities at the federal level. Its main organizational structure consists of a substantial array of secretariats, research institutes, development and support organizations, and social organizations:

<u>4 Secretariats:</u>

- R&D Policies and Programs (SEPED): main areas include: biotechnology, nanotechnology, emerging technologies in energy, biodiversity, climate science, ocean and earth science, environmental science.
- Information Technology Policy (SEPIN)
- Innovation and Technological Development (SETEC): design and coordinate the National Policy of Technological Development.
- Science and Technology for Social Inclusion (SECIS): promote and implement S&T programs to stimulate social and economic development in less privileged areas.

<u>13 Research Institutes:</u>

- Brazilian Institute of Physics Research (CBPF): performs basic research and provides post-graduate education in the area of Physics
- Renato Archer Research Institute (CenPRA): basic and applied research focused on information technology.
- Institute of Mineral Technology (CETEM)
- Brazilian Institute of Science and Technology Information (IBICT): promotes the use and dissemination of information in S&T at the national and international level.
- National Institute of Amazon Research (INPA)

- National Institute of Space Research (INPE): focuses on aerospace and earth/climate science
- National Institute of Technology (INT): with 26 laboratories, it promotes industrial innovation in the areas of chemistry, advanced materials, industrial engineering, energy and environment. It also provides technical assistance, certification, and professional development services to the industrial sector.
- National Institute of Research on the semi-Arid (INSA)
- National Laboratory of Astrophysics (LNA)
- National Laboratory of Computer Science (LNCS)
- Museum of Astronomy and Related Sciences (MAST)
- National Observatory
- Emilio Goeldi Museum of Natural History (MPEG)

<u>4 Development and Support Organizations</u>

- Brazilian Space Agency (AEB)
- National Commission for Nuclear Energy (CNEN)
- National Council for Scientific and Technological Development (CNPq): central agency within the MCT that finances basic research and promotes science education.
- Financing Agency for Studies and Projects (FINEP): Publicly owned company that combines resources to finance S&T activities in universities, research centers, institutes of technology, and private institutions.

<u>5 Social Organizations</u>

- Brazilian Association of Synchrotron Light (ABTLuS): operates the National Laboratory of Synchrotron Light (LNLS)
- Institute of Sustainable Development Mamiraua (IDSM): pursues research and manages resources related to environmental protection of the Amazon rain forest.
- Center for Strategic Studies and Management (CCGE): main activities include policy evaluation and prospective studies.
- National Institute for Applied Mathematics (IMPA)
- National Network of Research and Education (RNP)

The National Council for Science and Technology (CCT) is an advisory body that elaborates and proposes national S&T policy to the President. Most Brazilian states have secretaries for S&T whose agencies manage and provide funds to R&D activities. One worth mentioning is the Sao Paulo Foundation for Research Support (FAPESP), the oldest and largest one in the country (Cruz et al., 2006; European Commission, 2006).

Research is also done in some research institutes belonging to other Ministries. Particularly notable are the Brazilian Corporation for Agricultural Research (EMBRAPA) linked to the Ministry of Agriculture, and the Oswaldo Cruz Institute (FIOCruz) linked to the Ministry of Health. Some state institutes such as the Sao Paulo Technological Research Institute (IPT) are also important players. Research is done as well in some federal public companies, such as Petrobras (Brazilian Oil Company), and in the former state owned EMBRAER, a globally competitive aircraft manufacturer (Cruz et al., 2006; Cassiolato et al., 2003).

3.2 R&D Funding

This section draws on multiple sources, seeking to provide the most recent data on various aspects of research support (hence, the years cited vary). According to the MCT *Science & Technology Indicators*, in 2004, 20% of R&D was performed by the government, 40% by universities, and the remaining 40% by firms (public and private). Government funded about 58% of that R&D activity (and roughly 70-75% of that is Federal; the remainder is State); firms funded 40% (public and private); and universities, 2%.

Brazil's public and private R&D accounts for approximately 1% of GDP, and the country still suffers from the lack of investments and from the economic crises inherited from the 1980s and 1990s (European Commission, 2006). Although Brazil has a strong scientific infrastructure compared to other countries in Latin America, the country has not been able to transform its scientific output into sound economic and social development. Rates of innovation are low, only a very small part of the private sector engages in R&D activities – most of this by multinational companies. The number of patents issued is low compared to the scientific production (Zanotto, 2002; European Commission, 2006). Interaction among the public, academic, and private sectors lags. A recent innovation survey (PINTEC, 2003) carried out among Brazilian firms reveals that high costs and risks, lack of financial resources and qualified human resources, as well as lack of IT capabilities and technical standards, are the most common constraints to innovation.

In order to channel more resources to R&D activities, Brazilian policy makers conceived the Sectoral Funds program in 1999 (Arruda 2006; FINEP, 2006). Administered by FINEP, the program's main goal is to expand R&D financing alternatives by channeling funds from productive industrial sectors to university and other research players. This policy instrument targets a percentage of already existing corporate taxes to strategic areas of research. The decision making process includes the participation of academic, private, and government sectors, and research is directed to areas of industrial application to improve the country's rate of innovation (Sa, 2005). The fund's strategic areas at this time include:

- Aeronautics
- Agro-business
- Amazon Region
- Biotechnology
- Energy
- IT
- Infrastructure
- Mining
- Oil & Gas
- Transportation
- Space
- Telecommunications
- University-Industry Cooperation
- Water Resources
- Water Transportation & Ship Building

An important part of R&D in Brazil takes place in universities, which employ some 90% of the country's PhDs. The most important players are public universities, especially in the states of Sao Paulo and Rio de Janeiro. There are close to 77,600 scientists in the country, of which 48,000 hold PhDs. There are 200 public high education institutions, most of them funded at the federal and at the state level. The more than 1,600 private and community colleges focus mainly on educational activities. Brazil has more than 1,800 Masters courses and close to 1,000 PhD programs in the various fields of knowledge (FINEP, 2006).

According to the 2006 Ministry of Science and Technology Strategic Plan[10], Brazil's strategic R&D sectors include:

- Pharmaceuticals
- Information & communication technologies
- Biomass & energy
- Capital goods
- Aerospace
- Biotechnology, and
- Nanotechnology

Brazil is devoting special attention to nanotechnology. The National Plan of Development in Nanotechnology and Nanoscience had an R&D budget of US$30 million between 2005 and 2006.

Brazil devotes a significant part of its public research funds to agriculture, where R&D activity is mostly concentrated in the Ministry of Agriculture's Research Institute — EMBRAPA. Federal universities have undergraduate and graduate programs in agricultural, life, and related sciences. Also, State Agricultural Research Organizations (OEPAs – including, variously, foundations, institutes, and enterprises) emphasize adaptations and technologies suited for their regions. Brazil is also active in public health, having developed more than 60% of its vaccines in the country. Research in this area is concentrated in the Oswaldo Cruz Foundation (FIOCRUZ), linked to the Ministry of Health (Sa, 2005).

In 2005, the Brazilian federal government spent almost US$3 billion dollars in R&D activities.[11] Less than 2% of R&D funds went to defense-related purposes. Almost two-thirds of those funds

[10] Available at http://www.mct.gov.br/index.php/content/view/15854.html
[11] Relates to direct R&D activities, not including personnel expenses.

were split among Universities (27%), Agricultural research (21%, mostly done by EMBRAPA), and Health (15%).

There are no officially consolidated data that account for the total R&D expenditures by technological field or industry. Table 1 breaks federal expenses by destination and technological field, according to official statistics published by the Ministry of Science and Technology. The category under "Higher Education Institutions" includes public funding to universities as a whole. Government sources don't provide data by technology field funded within universities.

Table 1 - Brazil's R&D Inputs: Federal Government R&D Expenditures (2005)

	Million US dollars	**%**
Total	2,904	100
Higher Education Institutions (*)	793	27
Agriculture	607	21
Health	433	15
Industrial Technological Development	191	7
Infrastructure	206	7
Space (non-defense)	106	4
Energy	108	4
Defense	80	3
Environmental Science	69	2
Social Development and Services	70	2
Earth and Climate Science	27	1
Others	214	7

(*) Relates to federal expenses in R&D that went to higher education institutions. No further information is provided by field of research.
Source: S&T Indicators, Ministry of Science & Technology (http://www.mct.gov.br).

In 2004, Federal Universities spent over US$930 million current dollars in R&D, with most activities concentrated in the Southeastern states (mainly Sao Paulo, Rio de Janeiro, and Minas Gerais). State Universities invested US$660 million current dollars in the same year, with 90% of the investment concentrated in the state of Sao Paulo (MCT, *S&T Indicators*).

Following the Strategic Plan - 2006, as published by the Ministry of Science & Technology, Table 2 provides the MCT budget for 2006 in Science and Technology in selected sectors. In addition to regular funding programs, investments include the Sectoral Fund Program.

Table 2 - 2006 Federal Budget in Science and Technology in selected sectors

Technological Sector	US$ million
R&D Infrastructure and support	1,000
Nuclear	184
Aerospace	136
Electronics, Semiconductors, and Microelectronics	44
Pharmaceuticals	30
Nanotechnology	14
Biotechnology	14
Biodiesel	14
Biomass	9
ICT	9

Science and Technology Ministry (MCT): Strategic Plan 2006.
Available at www.mct.gov.br/index.php/content/view/.

According to the PINTEC Survey of 2003, R&D investments of manufacturing industries were estimated at US$1.8 billion current dollars. Table 3 shows the share of R&D investments by industrial sector.

Table 3 - Industrial R&D Investment (Manufacturing Sector 2003)

Industrial Sector	% of 2003 R&D investment (estimated at US$ 1.8 billion)
Transportation	37
Chemical products	12
Oil, other fossil fuels, nuclear, alcohol	12
Electronics and communications	7
Machines and equipments	7
Office equipment and IT	4
Food and beverage	4
Metallurgic industry	3
Electric machines and equipments	3
Rubber and plastic	2
Non-metallic minerals	1
Paper and cellulose	1
Others	7

Source: Innovation Survey Pintec (Brazilian Institute of Statistics – IBGE)

In closing, Brazil's R&D enterprise is structured and substantial. However, reporting on research funding does not enable straightforward delineation of the extent of support by topic area. This will limit comparison of observed R&D activity patterns to funding emphases.

4. Analytical Approach and Data Sources

Two major types of information are required for a country S&T assessment. One is the "research profile" – the general pattern of R&D activity observed over time ("Bibliometric results," presented in Section 5). The second breaks out this research activity by technology thrusts ("Taxonomies," provided in Section 6). Both derive from searches of two major international S&T databases.

Science Citation Index/ Social Science Citation Index ("SCI/SSCI")

For the present study, the SCI/SSCI are used as one combined source database. The retrieved data used for these analyses consist of selected journal records (including the fields of authors, titles, journals, author addresses, author keywords, abstract narratives, and references cited by each paper, but not the full text of the articles). We obtained these records by searching the SCI/ SSCI (via the Web of Science interface) for articles that contain at least one author with a Brazil address[12]. Our search and data retrieval effort was performed on February 28, 2007. The version of the SCI accesses about 5900 journals (mainly in physical and life sciences, bio-medicine, and some engineering basic research) and SSCI covers 1725 journals (mainly in the social sciences). As of June, 2007, SCI and SSCI together provide 35.8 million article abstracts.

We retrieved 17965 Brazilian records (including abstracts and references cited) for journal articles and reviews published in 2006. Taxonomy results were obtained using the titles and abstracts of these 17965 records. This dataset was also used for citation analysis and to explore current topics of research interest.

We drew additional samples of SCI/SSCI records (including abstracts, but not cited references) with publication dates at 5-year intervals from 1980 to 2005 for the publication trend analyses. The counts of publications downloaded for each year are given in the Bibliometric Results section of this report.

Engineering Index (EI) Compendex ("EC")

We also searched the EC database for articles with a Brazil address for the first author[13]. EC provides over 9 million abstract records taken from over 5,000 engineering journals, conferences and technical reports. [One disadvantage -- EC only provides first author institutional affiliation and address information.]

We downloaded 5253 records for Brazilian papers published in 2006 for bibliometric analyses. A larger sample was needed to generate meaningful taxonomy results so this sample was augmented to include publications from 2003 to 2007 (partial). We retrieved 21753 such records with abstracts on February 28, 2007. To analyze publication trends, EC records were also downloaded at 5-year intervals from 1980 to 2005 (as in the SCI/SSCI retrieval).

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[12] SCI/SSCI Search Strategy: CU=(Brasil or Brazil) ; DocType=Article OR Review; Language=All languages; Databases=SCI-EXPANDED, SSCI. Publication Year limits were set to retrieve records for selected years.

[13] EC Search Strategy: ((brazil OR brasil) WN CO); All document types, languages; Publication Year limits were set to retrieve records for selected years.

Bibliometric Analyses

We present two types of bibliometrics quantities: publication and citation information. Publication bibliometrics are counts of papers published by different entities. These metrics can be viewed as "output" measures. They are not direct measures of research quality, although there is some threshold quality level inferred, since (in the present study) these papers are published in the (typically) high caliber journals accessed by the SCI/ SSCI and EC.

Citation metrics are counts of citations to papers published by different entities. While citations are often used as "impact" (or quality) metrics (Garfield, 1985), much caution needs to be exercised in their frequency count interpretation, since there are numerous reasons why authors cite or do not cite particular papers (Kostoff, 1998b; MacRoberts and MacRoberts,1996).

Most "tech mining" studies analyze a particular technology (topic area) or a particular organization's R&D (c.f., Porter and Cunningham, 2005). Country studies cover the inherently wide range of technologies addressed by an entire country's R&D effort. In Section 5, we present some aggregate level findings to convey Brazil's emphases and overall leading institutions, major publication outlets, and so forth.

Section 6 categorizes Brazilian R&D, and then presents information on the activity within particular thrust areas. Rather than force fit the nation's R&D into pre-set categories, we apply clustering routines to generate a taxonomic structure for Brazil's S&T outputs. We do this separately for the SCI/SSCI and EC research papers. There is a significant degree of overlap in database coverage, but we feel it is better to treat these data separately because of content differences. Those include:

- SCI/SSCI provision of citation information and institutional affiliation/address information for all authors
- EC provision of class codes and controlled keywords

5. Bibliometric Results

For the aggregate Brazil datasets, this section presents:

- temporal publication trends
- information on the journals containing most articles
- journals cited most frequently by Brazilian authors
- most prolific institutions, and
- most frequently collaborating countries

We selectively include data from other countries to provide contextual comparisons. For this purpose, we tap the ONR Country reports for India and China. We also generate some counts for Argentina as another South American country, and for South Korea as a fast-industrializing country.

5.1 Overall Research Publication Activity Patterns

We present the SCI/SSCI and the EC Brazilian publication trends in the figures just below, showing comparable data for Argentina and South Korea.[14] The data underlying these figures appear in Table 4 and Table 5. The marked increases observed confound actual expansion of research activity with the increased coverage (e.g., additional journals) by the databases over time. [Later analyses will explore this aspect.]

Some points of interest:

- Brazilian R&D publication is substantial.
- Brazilian publication sharply increases from 1995 to 2000, and again to 2005.
- However, other countries also show sharp increases.
- Brazil outpaces Argentina — moving from rough equality (SCI/SSCI particularly) in the 1980s to triple the level as of 2005.
- Conversely, South Korea escalates from far fewer papers than Brazil in 1980 to far more in 2005.

Brazil's profile in these two global S&T databases is substantial – some 18,000 articles in SCI/SSCI and some 6,000 in EC in 2006. The trend in each shows strong growth – e.g., tripling from 1995 to 2005 in SCI/SSCI (Figure 2) and increasing nearly 6-fold in EC (Figure 3) for that period. Recent analyses (King, 2009) find Brazil's share of National Science Indicators has risen from 0.56% to 2.02% of the global National Science Indicators. Brazil is growing faster than Argentina, but slower than South Korea – two benchmarks.

[14] The counts for SCI/SSCI were retrieved using the database's Analyze function; For EC, lists of publication counts per year are generated automatically and are presented with the results of the search query.

Figure 2 - SCI/SSCI Publication Trend

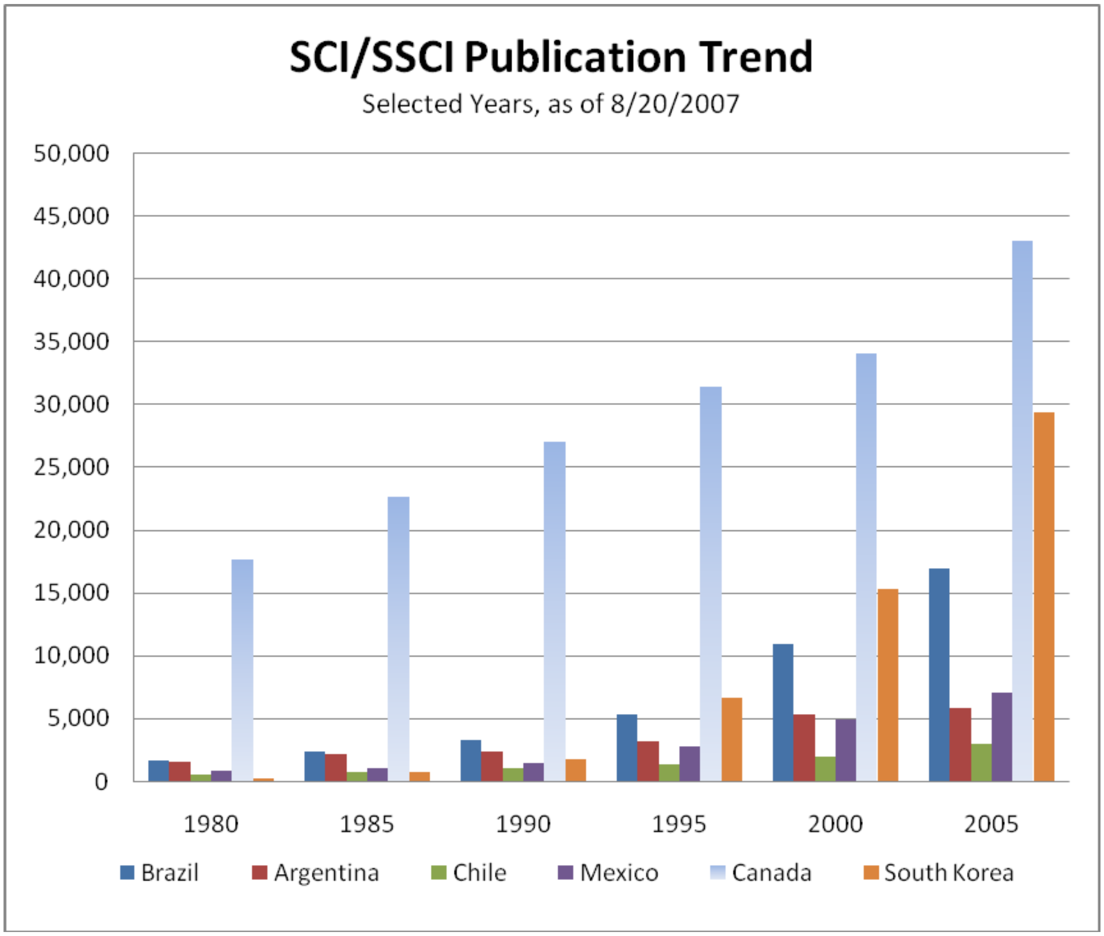
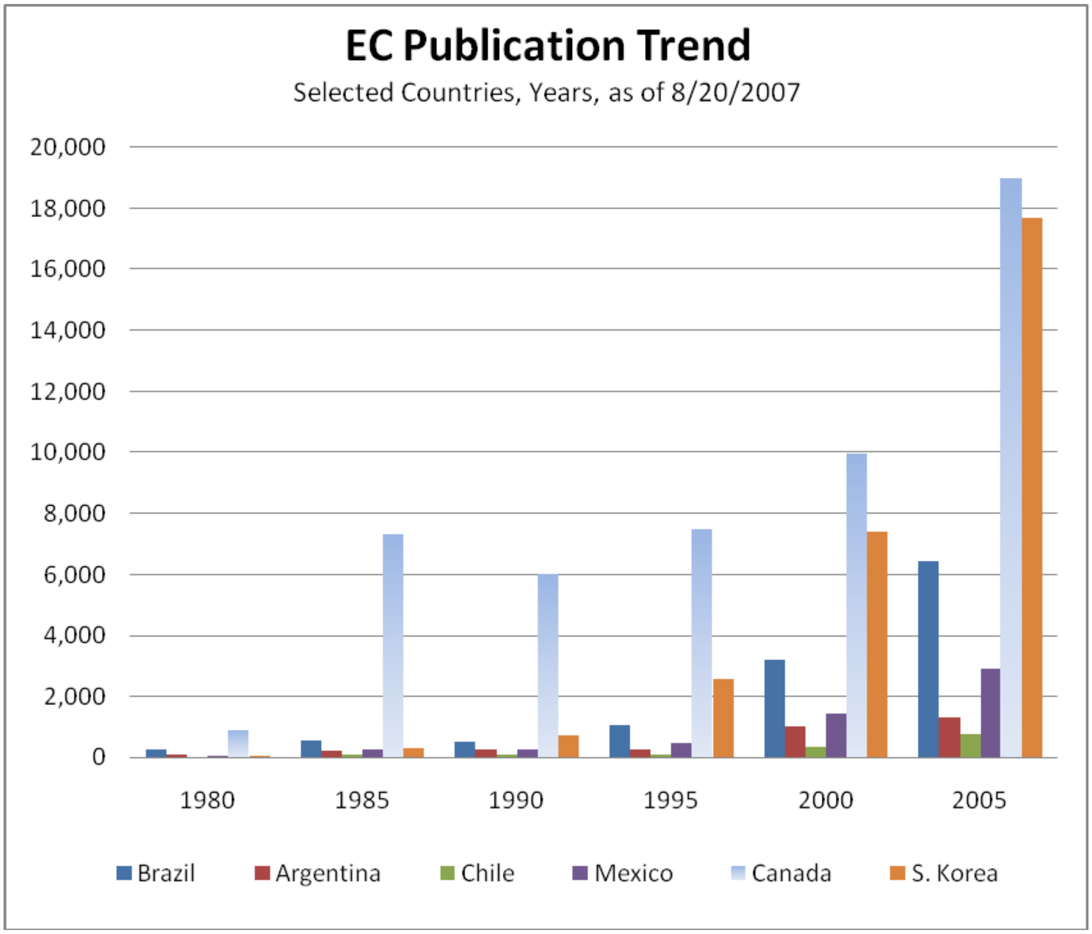


Figure 3 - EC Publication Trend



ONR review of an earlier draft report requested inclusion of other American countries – Chile, Mexico, and Canada. Those data are quite informative, suggesting merit in additional country studies to help understand our neighbors' research enterprises. Note, particularly, the extent of Canadian research publication! Chile shows a rate of increase intermediate between Argentina and Brazil in SCI/SSCI and signs of recent emergence in the engineering-oriented EC. Mexico keeps pace at about half the level of Brazilian research output.

Table 35 and Table 36 (Appendix) provide population and GDP data for these countries. Interestingly, Mexico and Canada show economic activity at about the same level as South Korea (between $1.1-1.2 Trillion); Brazil is almost 50% higher, while Argentina is half as large. Populations are very different. Canada's 33 million is a bit less than Argentina, but double Chile. South Korea is roughly 50% larger than Canada; Mexico's 109 million doubles that; Brazil's 190 million nearly doubles Mexico.

Table 4 - SCI/SSCI Publication Trend; Selected Countries, Years

SCI/SSCI	Publication Counts					
	Brazil	**Argentina**	**Chile**	**Mexico**	**Canada**	**S. Korea**
1980	1600	1552	494	783	17701	182
1985	2318	2141	721	1031	22654	714
1990	3256	2325	1003	1448	27034	1742
1995	5342	3174	1280	2793	31384	6584
2000	10966	5306	1910	4900	34113	15313
2005	16986	5847	3000	7086	43079	29432

Table 5 - EC Publication Trend; Selected Countries, Years

EC	Publication Counts					
	Brazil	**Argentina**	**Chile**	**Mexico**	**Canada**	**S. Korea**
1980	263	103	10	49	895	49
1985	539	219	101	254	7306	314
1990	517	248	100	245	6015	716
1995	1036	260	99	449	7468	2559
2000	3210	994	325	1410	9962	7405
2005	6443	1308	781	2916	18977	17710

The SCI/SSCI records contain a field called "Subject Category." It is essentially a classification by technical area of journals accessed by SCI/SSCI. The number of Subject Categories evolves gradually; there are currently about 245.[15] Table 6 lists the top ten Subject Categories for Brazilian research articles every fifth year since 1980. "Multidisciplinary Sciences" includes 51 journals as of 2006, including *Science* and *Nature.* As Brazilian S&T activities have expanded, articles in various Subject Categories appear to have overtaken the early concentration in Multidisciplinary Sciences. [Also, the expansion in Web of Science coverage has considerably extended the coverage into other Subject Categories.]

Note the Brazilian R&D emphases:

- Biochemistry & Molecular Biology has been a long-standing area of emphasis, and the leading Subject Category since 2000.
- Current Brazilian R&D is quite broadly distributed. Note that #2-#7 in the 2005 ranking all show over 600 articles. These prominent Subject Categories are quite dispersed (e.g.,

[15] Details are available through ISI's Web of Knowledge under "Journal Citation Reports."

we have to drop to #8 to find a second leading Subject Category in the same broad area – Chemistry).

- The Top 10 Subject Categories for 2005 include five life and biomedical sciences, and five physical sciences (two chemistry, two physics, and one materials science).
- So, **the life and biomedical sciences, and physical sciences stand forth in Brazilian research**, somewhat ahead of the information sciences, mathematics, engineering, and social sciences in prominence. This dominance extends from 1980 through 2005.
- Neurosciences enters the Top 10 in 1995 and rises strongly to #3 as of 2005.
- Pharmacology shows similarly strongly and increasingly.
- Physical Chemistry has been in the Top 10 since 1995, and is now second. Brazil's efforts in the Physical Sciences are also solid – five of the Top 10 Subject Categories could be grouped as such.

Table 7 compares the top Brazilian Subject Categories with those of four other countries for 2005.[16] Emphases are really quite varied so that examination of the Subject Category distribution speaks informatively to Brazilian concentrations.

[16] We obtained the counts for Argentina and South Korea for this study using the SCI Analyze function; the counts for China and India are from the India/China Comparison study published by Kostoff et al (2006).

Table 6 - Top SCI/SSCI Subject Categories for Brazilian Papers; Selected Years

1980		1985		1990		1995		2000		2005	
Multidisciplinary Sciences	125	Agriculture, Multidisciplinary	181	Agriculture, Multidisciplinary	212	Biology	309	Biochemistry & Molecular Biology	668	Biochemistry & Molecular Biology	798
Physics, Condensed Matter	95	Biochemistry & Molecular Biology	111	Astronomy & Astrophysics	182	Biochemistry & Molecular Biology	273	Veterinary Sciences	515	Chemistry, Physical	678
Medicine, General & Internal	89	Biology	110	Biology	159	Physics, Condensed Matter	265	Physics, Multidisciplinary	442	Neurosciences	646
Veterinary Sciences	79	Physics, Condensed Matter	106	Biochemistry & Molecular Biology	150	Physics, Multidisciplinary	221	Neurosciences	437	Pharmacology & Pharmacy	642
Biochemistry & Molecular Biology	77	Physics, Multidisciplinary	106	Tropical Medicine	144	Chemistry, Physical	203	Chemistry, Physical	393	Physics, Multidisciplinary	625
Physics, Multidisciplinary	67	Tropical Medicine	103	Physics, Multidisciplinary	142	Materials Science, Multidisciplinary	196	Physics, Condensed Matter	392	Materials Science, Multidisciplinary	622
Genetics & Heredity	52	Genetics & Heredity	102	Physics, Condensed Matter	136	Chemistry, Multidisciplinary	186	Materials Science, Multidisciplinary	366	Veterinary Sciences	622
Plant Sciences	51	Public, Environmental & Occupational Health	97	Genetics & Heredity	124	Medicine, Research & Experimental	186	Pharmacology & Pharmacy	354	Chemistry, Multidisciplinary	488
Pharmacology & Pharmacy	46	Multidisciplinary Sciences	71	Pharmacology & Pharmacy	107	Agriculture, Multidisciplinary	174	Chemistry, Multidisciplinary	337	Zoology	488
Mathematics	44	Medicine, Research & Experimental	70	Public, Environmental & Occupational Health	103	Neurosciences	173	Physics, Applied	336	Physics, Condensed Matter	473

Table 7 - Top SCI/SSCI Subject Categories for Selected Countries; (2005)

Brazil		Argentina		India		South Korea		China	
2005 Total	16936	**2005 Total**	5847	**2005 Total**	25637	**2005 Total**	29432	**2005 Total**	72310
Biochemistry & Molecular Biology	798	Biochemistry & Molecular Biology	361	Materials Science, Multidisciplinary	1634	Materials Science, Multidisciplinary	2286	Materials Science, Multi- Disciplinary	7091
Chemistry, Physical	678	Chemistry, Physical	298	Chemistry, Multidisciplinary	1553	Physics, Applied	2225	Chemistry, Physical	4653
Neurosciences	646	Plant Sciences	225	Chemistry, Organic	1542	Engineering, Electrical & Electronic	2141	Physics, Multi-Disciplinary	4478
Pharmacology & Pharmacy	642	Food Science & Technology	182	Chemistry, Physical	1470	Computer Science, Theory & Methods	1848	Chemistry, Multi-Disciplinary	4301
Physics, Multidisciplinary	625	Physics, Multidisciplinary	180	Biochemistry & Molecular Biology	1166	Biochemistry & Molecular Biology	1642	Physics, Applied	3823
Materials Science, Multidisciplinary	622	Engineering, Chemical	171	Physics, Condensed Matter	971	Chemistry, Multidisciplinary	1438	Computer Science, Theory & Methods	3348
Veterinary Sciences	622	Ecology	170	Physics, Multidisciplinary	953	Pharmacology & Pharmacy	1049	Metallurgy & Metallurgical Engineering	3093
Chemistry, Multidisciplinary	488	Cell Biology	167	Physics, Applied	802	Physics, Condensed Matter	1014	Biochemistry & Molecular Biology	2789
Zoology	488	Endocrinology & Metabolism	167	Engineering, Chemical	788	Physics, Multidisciplinary	930	Physics, Condensed Matter	2738
Physics, Condensed Matter	473	Pharmacology & Pharmacy	167			Chemistry, Physical	905		
Chemistry, Analytical	439	Physics, Condensed Matter	164			Biotechnology & Applied Microbiology	882		
Dentistry, Oral Surgery & Medicine	425	Astronomy & Astrophysics	163			Cell Biology	814		

Note: Naturally occurring discontinuities were used to truncate these "Top N' lists at 9-12 entries.

The EC records contain two thematic fields [Classification Codes and Controlled Vocabulary (i.e., keywords)] that provide a second perspective into Brazilian R&D areas of emphasis. Table 8 shows the change in Class Codes for Brazil over time. Table 9 compares Brazil with four other countries. Unlike the results for ISI Web of Science Subject Categories, note the high commonality of EC Class Codes across countries. This implies that the distribution of Class Code frequencies tells us more about EC coverage emphases than about national differences. This suggests that one should not place too much reliance on the indicated Brazilian Class Code distribution in assessing Brazil's relative R&D strengths. Nonetheless, the EC Class Codes can be used to identify who is actively engaging in particular research domains of interest. [This is best done by accessing these data via the software tool, TechOASIS – see Section 7.]

The same caution pertains to Table 10 and Table 11. The leading EC Controlled Keywords show much in common across these five countries. So, they are not so useful in discerning Brazilian areas of emphasis. Yet, they do provide some indication of activity levels and a good vehicle to target "who is doing what" on particular topics of interest.

Table 8 - Top EC Classification Codes for Brazilian Papers; Selected Years

1980		1985		1990		1995		2000		2005	
804 Chemical Products Generally	56	921 Applied Mathematics	89	921 Applied Mathematics	131	921.6 Numerical Methods	333	921.6 Numerical Methods	495	802.2 Chemical Reactions	1057
523 Liquid Fuels	33	804 Chemical Products Generally	76	804 Chemical Products Generally	98	723.5 Computer Applications	189	723.5 Computer Applications	406	802.3 Chemical Operations	1007
545 Iron and Steel	29	701 Electricity and Magnetism	75	723 Computer Software, Data Handling and Applications	93	701.1 Electricity: Basic Concepts & Phenomena	164	921 Applied Mathematics	401	921 Applied Mathematics	974
803 Chemical Agents and Basic Industrial Chemicals	25	723 Computer Software, Data Handling and Applications	59	701 Electricity and Magnetism	73	731.1 Control Systems	115	804.2 Inorganic Compounds	397	804.1 Organic Compounds	970
531 Metallurgy and Metallography	19	931 Applied Physics Generally	58	931 Applied Physics Generally	72	741.1 Light/Optics	115	931.2 Physical Properties of Gases, Liquids & Solids	364	741.1 Light/Optics	861
921 Applied Mathematics	16	545 Iron and Steel	50	741 Light, Optics and Optical Devices	63	714.2 Semiconductor Devices & Integrated Circuits	110	802.2 Chemical Reactions	352	723.5 Computer Applications	846
802 Chemical Apparatus and Plants; Unit Operations; Unit Processes	15	714 Electronic Components and Tubes	42	802 Chemical Apparatus and Plants; Unit Operations; Unit Processes	47	921.1 Algebra	109	931.3 Atomic & Molecular Physics	292	931.2 Physical Properties of Gases, Liquids & Solids	785
421 Strength of Building Materials; Mechanical Properties	14	731 Automatic Control Principles and Applications	39	801 Chemistry	45	804.2 Inorganic Compounds	109	701.1 Electricity: Basic Concepts & Phenomena	281	804.2 Inorganic Compounds	761
533 Ore Treatment and Metal Refining	14	802 Chemical Apparatus and Plants; Unit Operations; Unit Processes	37	714 Electronic Components and Tubes	37	931.2 Physical Properties of Gases, Liquids & Solids	105	802.3 Chemical Operations	277	931.3 Atomic & Molecular Physics	688

931 Applied Physics Generally	13	708 Electric & Magnetic Materials	36	712 Electronic and Thermionic Materials	35	921 Applied Mathematics	92	741.1 Light/Optics	254	701.1 Electricity: Basic Concepts & Phenomena	672
723 Computer Software, Data Handling and Applications	12	933 Solid State Physics	34	731 Automatic Control Principles and Applications	34	802.2 Chemical Reactions	84	931.1 Mechanics	254	921.6 Numerical Methods	668

Table 9 - Top EC Classification Codes for Selected Countries; (2005)

Brazil		Argentina		India		South Korea		China	
Chemical Reactions	1057	Chemical Reactions	324	Chemical Reactions	2719	Computer Applications	3140	Chemical Reactions	9188
Chemical Operations	1007	Organic Compounds	307	Organic Compounds	2505	Semiconductor Devices and Integrated Circuits	2784	Computer Applications	8639
Applied Mathematics	974	Chemical Operations	266	Chemical Operations	2155	Electricity: Basic Concepts and Phenomena	2760	Applied Mathematics	8228
Organic Compounds	970	Inorganic Compounds	226	Inorganic Compounds	2154	Chemical Reactions	2685	Numerical Methods	7927
Light/Optics	861	Mathematics	221	Physical Properties of Gases, Liquids & Solids	1816	Inorganic Compounds	2488	Inorganic Compounds	7921
Computer Applications	846	Physical Properties of Gases, Liquids and Solids	199	Atomic & Molecular Physics	1654	Light/Optics	2410	Physical Properties of Gases, Liquids & Solids	7116
Physical Properties of Gases, Liquids & Solids	785	Atomic and Molecular Physics	189	Light/Optics	1595	Telecommunication; Radar, Radio and Television	2217	Chemical Operations	6974
Inorganic Compounds	761	Light/Optics	183	Electricity: Basic Concepts & Phenomena	1500	Physical Properties of Gases, Liquids and Solids	2169	Light/Optics	6702
Atomic & Molecular Physics	688	Physical Chemistry	172	Applied Mathematics	1491	Data Processing and Image Processing	2164	Organic Compounds	6114
Electricity: Basic Concepts & Phenomena	672	Electricity: Basic Concepts and Phenomena	164	Physical Chemistry	1479	Chemical Operations	2114	Strength of Building Materials; Mechanical Properties	5671
Numerical Methods	668	Numerical Methods	155			Mathematics	2036		
Chemistry	643					Numerical Methods	1834		

Table 10 - Top EC Controlled Keywords for Brazilian Papers; Selected Years

1980		1985		1990		1995		2000		2005	
Automotive fuels	14	Mathematical techniques	48	Mathematical techniques	31	Mathematical models	247	Mathematical models	510	Mathematical models	890
Mathematical models	12	Applications	40	Mathematical models	21	Computer simulation	150	Computer simulation	326	Computer simulation	614
Ethanol	8	Mathematical models	22	Computer simulation	13	Algorithms	97	Algorithms	177	Problem solving	314
Stainless steel	6	Computer programming	22	Mathematical Techniques--Matrix Algebra	12	Calculations	83	Thermal effects	117	Algorithms	288
Metallography	6	Analysis	21	Computer Programming--Algorithms	11	Matrix algebra	59	Optimization	94	Optimization	243
Heat transfer	5	Algorithms	19	Optimization	10	Performance	53	Approximation theory	87	Scanning electron microscopy	207
Structural analysis	5	Brazil	19	Computer software	9	Vectors	50	Scanning electron microscopy	79	Parameter estimation	205
Lasers, Semiconductor	5	Crystals	13	Ceramic materials	8	Approximation theory	49	Synthesis (chemical)	78	Thermal effects	202
Magnetic materials	5	Magnetic materials	11	Computer programming	8	Electric currents	48	Finite element method	75	Synthesis (chemical)	184
Composite materials	5	Measurements	11	Spectroscopic analysis	7	Optimization	46	Matrix algebra	72	X ray diffraction analysis	162
Blast furnace practice	5	Dams	10	Applications	7	Thermal effects	45	Problem solving	71	Oxidation	153
Flow of fluids	5										

Table 11 - Top EC Controlled Keywords for Selected Countries; (2005)

Brazil		**Argentina**		**India**		**South Korea**		**China**	
Mathematical models	890	Mathematical Models	202	Mathematical Models	1278	Computer Simulation	1914	Computer Simulation	6873
Computer simulation	614	Computer Simulation	105	Synthesis Chemical	906	Mathematical Models	1679	Mathematical Models	6632
Problem solving	314	Reaction Kinetics	69	Computer Simulation	796	Algorithms	1549	Algorithms	3224
Algorithms	288	Synthesis (Chemical)	56	X Ray Diffraction Analysis	553	Nanostructured Materials	819	Synthesis (Chemical)	3095
Optimization	243	Catalysts	51	Nanostructured Materials	533	Thin Films	800	Nanostructured Materials	2806
Scanning electron microscopy	207	Adsorption	48	Algorithms	524	Optimization	799	Scanning Electron Microscopy	2592
Parameter estimation	205	Problem Solving	47	Optimization	445	Synthesis (Chemical)	717	X Ray Diffraction Analysis	2507
Thermal effects	202	Thermal Effects	47	Scanning Electron Microscopy	442	Problem Solving	664	Optimization	2463
Synthesis (chemical)	184	Approximation Theory	46	Reaction Kinetics	432	Scanning Electron Microscopy	562	Finite Element Method	1919
X ray diffraction analysis	162	Optimization	45	Thin Films	382	Electric Potential	507	Transmission Electron Microscopy	1831
Oxidation	153	Oxidation	42			Network Protocols	505		
Approximation theory	152	Diffusion	41			Microstructure	467		

5.2 Journals

The journals containing the most research articles with at least one Brazilian author (from the total downloaded SCI/SSCI 2006 dataset) are shown in Table 12. The "themes" reflect our judgment based on journal title – to provide a quick way to gauge Brazilian emphases. These reaffirm Table 6's pointers to Brazilian research in the life and biosciences and physical sciences as more prominent than their research in information sciences, math, engineering, or social sciences.

Not surprisingly, the leading journals are primarily Brazilian. And, these tend to have lower impact factors than the international journals appearing in the list (in bold -- e.g., *Physical Review*, *Astronomy & Astrophysics*).

Table 12 - Top Journals for Brazilian Publication (2006)

# Papers 2006	SCI/SSCI Journals	Impact Factor	SCI/SSCI Acc Year	Theme
253	Revista Brasileira De Zootecnia-Brazilian Journal Of Animal Science	0.250	1998	Animal
243	Pesquisa Agropecuaria Brasileira	0.181	1981	Agri
209	Quimica Nova	0.650	1995	Chem
198	Arquivos De Neuro-Psiquiatria	0.430	1977	Psych
186	Brazilian Journal Of Physics	0.445	1998	Phys
172	Brazilian Journal Of Medical And Biological Research	0.859	1981	Med
161	Journal Of The Brazilian Chemical Society	1.097	1995	Chem
160	Memorias Do Instituto Oswaldo Cruz	0.847	1966	Med
153	Zootaxa*	0	2004*	Animal
152	Brazilian Archives Of Biology And Technology	0.131	1998	Bio
151	Revista Brasileira De Zoologia*	0	2005*	Animal
149	**Physical Review B**	3.185	1964	Phys
139	Arquivo Brasileiro De Medicina Veterinaria E Zootecnia	0.114	1983	Animal
139	Revista De Saude Publica	0.287	1982	Med
117	**Physical Review D**	4.852	1970	Phys
106	Neotropical Entomology*	0	2004*	Animal
105	Revista Brasileira De Ciencia Do Solo	0.289	2003	Geo
97	Genetics And Molecular Biology	0.373	1998	Science
96	**Physical Review E**	2.418	1993	Phys
92	**Astronomy & Astrophysics**	4.223	1969	Phys
89	**Journal Of Non-Crystalline Solids**	1.264	1974	Mat'ls
82	Revista Da Sociedade Brasileira De Medicina Tropical*	0	2005*	Med
79	**Physica A-Statistical Mechanics And Its Applications**	1.332	1976	Phys
76	**Journal Of Applied Physics**	2.498	1937	Phys
76	Scientia Agricola	*0*	2004	Agri
# Papers 2006	**EC Journals (Not covered by SCI/SSCI)**			**Theme**
52	**Proceedings of SPIE - The Int'l. Soc. for Optical Eng.**			Phys
32	Journal of the Brazilian Soc. of Mech. Sci. & Eng.			Phys
30	Scientia Forestalis/Forest Sciences			Agri

Notes to Table 12: Non-Brazilian journals appear in bold.
* Journals added into SCI/SSCI in 2004 or 2005 that, as yet, do not have impact factors associated with them.

Note that all the leading international journals included reside in the physical sciences. In part this may reflect Brazilian participation in large team physics research projects. Table 13 and Table 14 show the corresponding top journal lists for India and China. Note that these countries' leading international publication journals are also predominately in the physical sciences.

Table 13 - SCI/SSCI Journals Containing Most Articles by India Authors
(Kostoff-India/China Comparison Paper)

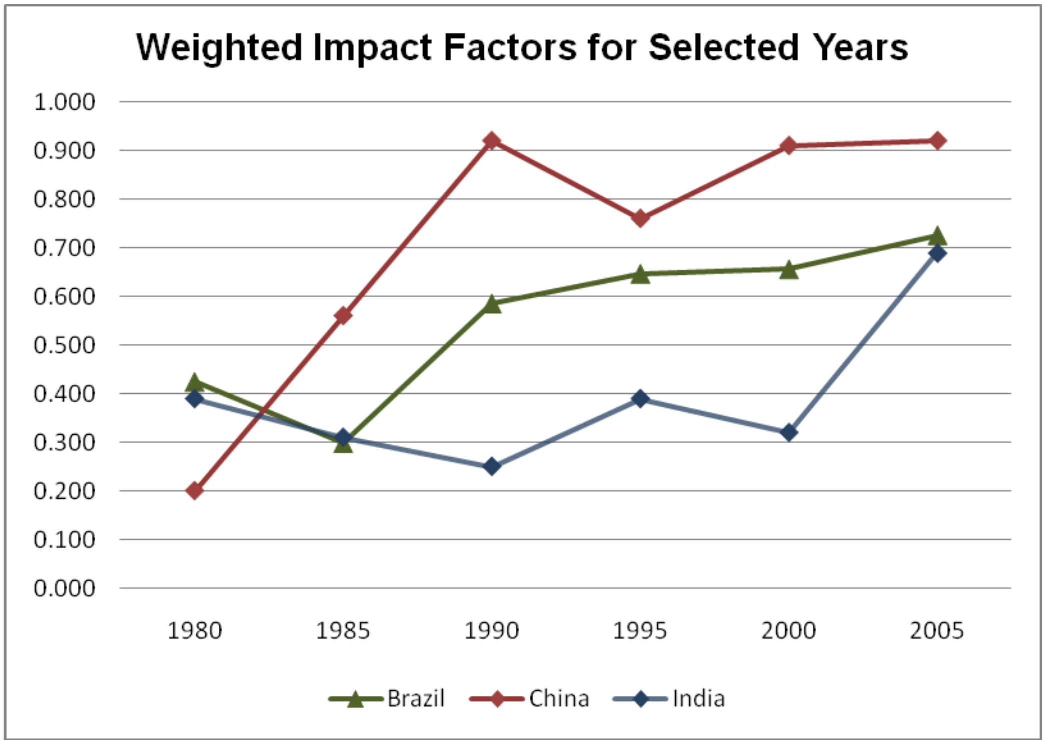
# Papers 2005	Journal	Impact Factor	SCI Acc Year	Theme
457	Current Science	0.728	1961	Science
443	Indian Veterinary Journal	0.052	1977	Vet
381	Indian Journal Of Animal Sciences	0.090	1976	Vet
346	Asian Journal Of Chemistry	0.153	1995	Chem
272	Tetrahedron Letters	2.477	1959	Chem
267	Journal Of The Indian Chemical Society	0.340	1946	Chem
242	Acta Crystallographica Section E-Structure Reports Online	0.581	2001	Matls
240	Indian Journal Of Chemistry Section B-Organic Chemistry Including Medicinal Chemistry	0.446	1976	Chem
217	Journal Of Food Science And Technology-Mysore	0.123	1976	Agri
187	Physical Review B	3.185	1964	Physics
172	Indian Journal Of Agricultural Sciences	0.084	1966	Agri
170	Indian Journal Of Physics And Proceedings Of The Indian Association For The Cultivation Of Science	0.072	1968	Physics
146	Pramana-Journal Of Physics	0.380	1990	Physics
138	Indian Journal Of Chemistry Section A-Inorganic Bio-Inorganic Physical Theoretical & Analytical Chemistry	0.632	1976	Chem
134	Indian Journal Of Pure & Applied Physics	0.495	1964	Physics
134	Journal Of Applied Polymer Science	1.072	1965	Matls
132	Journal Of Applied Physics	2.498	1937	Physics
122	Spectrochimica Acta Part A-Molecular And Biomolecular Spectroscopy	1.290	1973	Chem
115	Journal Of The Geological Society Of India	0.217	1970	Geol
114	Indian Journal Of Heterocyclic Chemistry	0.312	1995	Chem
109	Bulletin Of Materials Science	0.777	1986	Matls
109	Physical Review D	4.852	1970	Physics
107	Journal Of Physical Chemistry B	4.033	1997	Chem
107	Physica B-Condensed Matter	0.796	1990	Physics
105	Physical Review Letters	7.489	1958	Physics

Table 14 - SCI/SSCI Journals Containing Most Articles by China Authors (Kostoff-India/China Comparison Paper)

# Papers 2005	Journal	Impact Factor	SCI Acc Year	Theme
1494	Acta Crystallographica Section E-Structure Reports Online	0.581	2001	Matls
1032	Acta Physica Sinica	1.051	1999	Physics
920	Chinese Physics Letters	1.276	1989	Physics
872	Rare Metal Materials And Engineering	0.400	1997	Matls
610	Spectroscopy And Spectral Analysis	0.557	1999	Physics
547	Physical Review B	3.185	1964	Physics
531	Chemical Journal Of Chinese Universities-Chinese	0.771	1995	Chem
528	Materials Letters	1.299	1985	Matls
520	Pricm 5: The Fifth Pac. Rim Int'l Conference On Advanced Materials And Processing, Pts 1-5*	0	2005*	Matls
513	Chinese Science Bulletin	0.783	1989	Science
509	Applied Physics Letters	4.127	1962	Physics
504	Chinese Chemical Letters	0.355	1995	Chem
497	Chinese Physics	1.256	1981	Physics
479	Transactions Of Nonferrous Metals Society Of China	0.302	1995	Matls
459	Chinese Journal Of Analytical Chemistry	0.397	1999	Chem
453	Communications In Theoretical Physics	0.872	1985	Physics
423	Acta Chimica Sinica	0.845	1980	Chem
418	Chinese Journal Of Inorganic Chemistry	0.697	1999	Chem
410	Chinese Medical Journal	0.561	1964	Med
405	Journal Of Physical Chemistry B	4.033	1997	Chem
398	High-Performance Ceramics Iii, Pts 1 And 2*	0	2005*	Matls
346	Journal Of Rare Earths	0.249	1995	Matls
340	Physics Letters A	1.550	1979	Physics
338	Journal Of Crystal Growth	1.681	1971	Matls
323	Chinese Journal Of Chemistry	0.819	1995	Chem

Figure 4 shows the trend in journal impact factor – an indicator of quality – from 1980 through 2005 based on SCI/SSCI results. We include corresponding trends for China and India for comparison (taken from Kostoff et al., to appear). While all three countries show marked increases, the patterns are not identical. India's increase is essentially restricted to the most recent 5-year period. In contrast, China rose sharply from 1980 to 1990, and has held quite steady since then. Brazil shows a somewhat steadier progression. On this basis, note particularly that Brazil's research appears on par with India, not too far behind China's.

Figure 4 - Weighted Impact Factor Trend



Note: When journal has no impact factor assigned, used zero (0).

How does collaboration among Brazil and other countries impact the journals in which Brazilian authors publish? We performed a brief analysis, examining two cases. The first case represents articles that indicate collaboration of Brazilian and foreign authors. The second case represents articles published by Brazilian authors. The differences between the two cases reflect the impact of collaboration.

All research articles in the SCI/SSCI having at least one author with a Brazilian address, and publication date of 2006, were retrieved and imported to TechOASIS. There were 17965 records. These were divided into two discrete sub-datasets: 12519 records for which all authors have Brazilian addresses (a.k.a. "Brazil Only" papers) and 5446 records (30.3%) for papers in which at least one author indicates an address in a country other than Brazil (a.k.a. "International Collaborations"). A sample of 29 Journals with Impact Factor values >10 was examined; the details are shown in Table 15. The message is unmistakable – see the Table Totals – international collaboration dramatically boosts the prospects of publication in high-impact international journals.

Table 15 - Effect of International Collaboration on Publication in High Impact Factor Journals
(SCI/SSCI 2006 records; sorted by journal's impact factor)

Journal Title	Impact Factor	# Papers in 2006	
		Int'l. Collab.	Brazil Only
New England Journal Of Medicine	44.0	5	
Science	30.9	6	
Nature Reviews Immunology	30.5	1	
Nature	29.3	9	
Nature Medicine	28.9	4	
Nature Genetics	25.8	2	1
Lancet	23.9	7	
JAMA-Jnl of the Amer. Med. Assoc.	23.5	2	
Annual Review Of Plant Biology	17.8		1
Nature Materials	15.9		1
Immunity	15.2	1	
Journal Of Clinical Investigation	15.1	1	
Trends In Ecology & Evolution	14.9	1	
Astrophysical Journal Supplement Series	14.4	3	
Trends In Neurosciences	14.3	1	
Neuron	14.3	2	
Annals Of Internal Medicine	13.3	2	
American Journal Of Human Genetics	12.6	3	
Gastroenterology	12.4	1	1
Journal Of Clinical Oncology	11.8	3	
Circulation	11.6	1	3
Lancet Neurology	11.2	2	1
Physics Reports-Review Sec. of Phys Lett.	10.5	2	1
Trends In Pharmacological Sciences	10.4		1
Systematic Biology	10.3	2	
Proc. Nat. Acad. Sci – USA	10.2	19	4
Genome Research	10.1		1
Blood	10.1	3	2
Lancet Infectious Diseases	10.0	1	
Total		**84**	**17**
% Total		**83.2%**	**16.8%**

As a small scale exploration, we compared the extent of publication in three prominent journals. The journals are:

- Journal of the American Chemical Society
- Physical Review Letters
- Journal of Biological Chemistry

The number of publications in the three journals, taken as a whole, was calculated for Brazil[17] and compared with that of India and China.[18] A breakout of each country's publication activity per year in a particular journal is included in the appendix. Brazil compares closely with India on this metric, but China has jumped way ahead. Of course, China has shown striking relative growth in most S&T publication measures over the past five years compared to any countries.

Figure 5 - Brazilian Publications for 3 High Impact Factor Journals

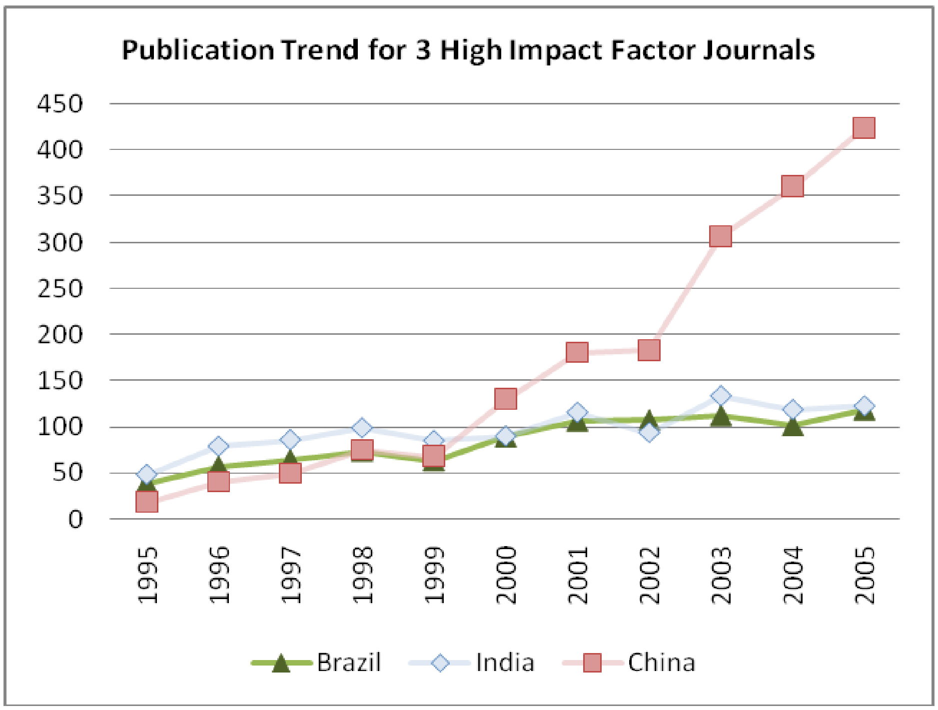


Table 16 shows what research knowledge is most prominently drawn upon by Brazilian research article authors. Their 9 most cited sources are highly regarded international journals; the first Brazilian journal appears as #10 – the Brazilian Journal of Medical and Biological Research. Table 17 and Table 18 present the corresponding lists for India and China. We observe that the Brazilians appear relatively more engaged in medical research based on this metric.

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[17] The Web of Science 'Analyze' function was used to determine the number of Brazilian publications.
[18] www.fas.org/irp/world/india/research.pdf.

Table 16 - Journals Most Cited by Brazilian Authors
(Source – SCI/SSCI 2006 database)

# Records	Cited Journal	Impact Factor	Theme
2657	Nature	29.273	Science
2285	Science	30.927	Science
1938	P Natl Acad Sci Usa	10.231	Science
1609	J Biol Chem	5.854	Biochemistry
1523	Phys Rev Lett	7.489	Physics
1101	Lancet	23.878	Medicine
1064	New Engl J Med	44.016	Medicine
1045	Phys Rev B	3.185	Physics
970	J Am Chem Soc	7.419	Chemistry
757	Braz J Med Biol Res	0.859	Medicine
700	Biochem Bioph Res Co	3.000	Biochemistry
666	Anal Biochem	2.670	Biochemistry
666	J Appl Phys	2.498	Physics
631	J Chem Phys	3.138	Chemistry
625	Appl Phys Lett	4.127	Physics
604	Jama-J Am Med Assoc	23.494	Medicine
561	Nucleic Acids Res	7.552	Biochemistry
559	J Clin Invest	15.053	Medicine
548	Quim Nova	0.650	Chemistry
546	Febs Lett	3.415	Biochemistry
546	J Clin Microbiol	3.537	Biochemistry

Table 17 - Journals most Cited by Indian Authors
(Papers published in 2005; from India Study PDF)

# Records	Cited Journal	Impact Factor	Theme
5559	J Am Chem Soc	7.419	Chemistry
4494	Phys Rev Lett	7.489	Physics
3835	Phys Rev B	3.185	Physics
3399	Nature	29.273	Science
3058	J Biol Chem	5.854	Chemistry
2834	Science	30.927	Science
2809	Tetrahedron Lett	2.477	Chemistry
2704	J Chem Phys	3.138	Chemistry
2541	J Org Chem	3.675	Chemistry
2299	P Natl Acad Sci USA	10.231	Science
2258	Phys Rev D	4.852	Physics
2144	Inorg Chem	3.851	Chemistry
2036	J Phys Chem-USA	0	Physics
1758	J Appl Phys	2.498	Physics
1635	Appl Phys Lett	4.127	Physics
558	Chem Rev	20.869	Chemistry
544	Angew Chem Int Edit	9.596	Chemistry
465	J Phys Chem B	4.033	Physics
465	Tetrahedron	2.61	Chemistry
421	Phys Lett B	5.301	Physics
417	J Appl Polym Sci	1.072	Materials Science

Table 18 - Journals most Cited by Chinese Authors
(Papers published in 2002; from India Study PDF)

# Records	Cited Journal	Impact Factor	Theme
2592	Phys Rev Lett	7.489	Physics
2196	J Am Chem Soc	7.419	Chemistry
2191	Nature	29.273	Science
2027	Phys Rev B	3.185	Physics
1995	Science	30.927	Science
1737	Appl Phys Lett	4.127	Physics
1433	J Appl Phys	2.498	Physics
1174	J Chem Phys	3.138	Chemistry
976	P Natl Acad Sci USA	10.231	Science
924	Anal Chem	5.635	Chemistry
917	J Biol Chem	5.854	Chemistry
834	Phys Rev D	4.852	Physics
779	Phys Rev A	2.997	Physics
757	Inorg Chem	3.851	Chemistry
738	J Phys Chem-US		Physics
738	J Am Ceram Soc	1.586	Materials Science
714	Macromolecules	4.024	Chemistry
687	Angew Chem Int Edit	9.596	Chemistry
641	Astrophys J	6.308	Physics
612	J Org Chem	3.675	Chemistry

5.3 Institutions

Brazilian research shows a strongly academic institutional base. The two parts of Figure 6 show considerably greater governmental and non-governmental organization (e.g., research lab) participation in SCI/SSCI than in EC publication activity. This seems largely attributable to considerable collaboration led by academics with these labs (that EC cannot pick up as it only tracks the organizational affiliation of the first author). In any event, Brazilian fundamental research is strongly led by university researchers. Table 19 provides specifics.

Figure 6 - Academic/Government/Industry Breakouts

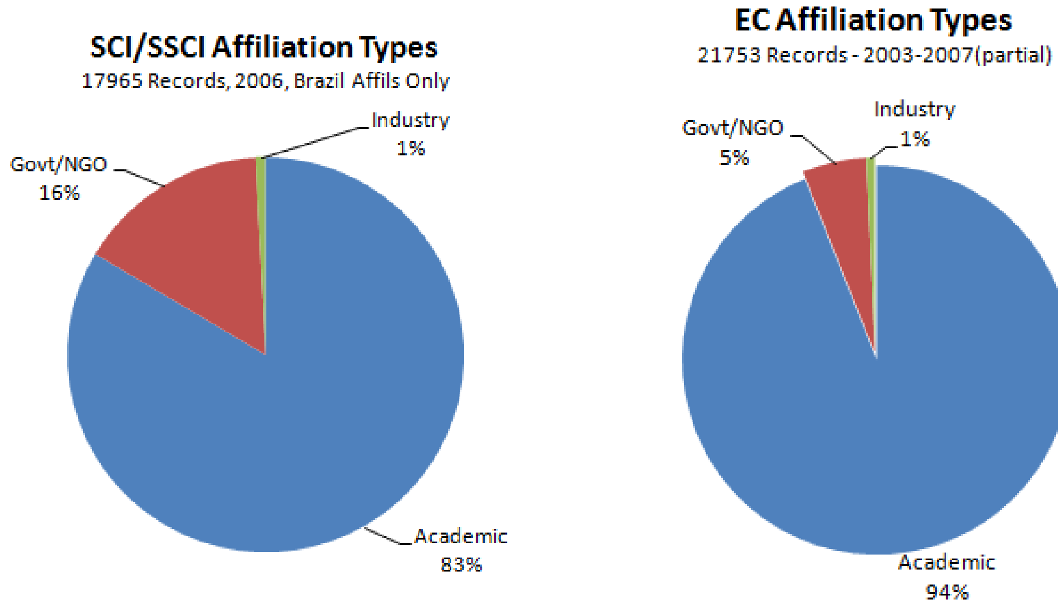


Table 19 - Most Prolific Brazilian Institutions for Selected Years

1985		Wtd Impact Factor		1995		Wtd Impact Factor		2005		Wtd Impact Factor	
# Recs	**Institution Name**	**Jnls w/ Imp Fac**	**All Jnls**	**# Recs**	**Institution Name**	**Jnls w/ Imp Fac**	**All Jnls**	**# Recs**	**Institution Name**	**Jnls w/ Imp Fac**	**All Jnls**
564	Univ Sao Paulo	2.06	1.36	1283	Univ Sao Paulo	2.27	1.98	4172	Univ Sao Paulo	2.08	1.96
191	Univ Fed Rio de Janeiro	2.27	1.50	563	Univ Estadual Campinas	1.78	1.58	1658	Univ Estadual Campinas	1.82	1.76
165	Univ Estadual Campinas	1.60	1.13	559	Univ Fed Rio de Janeiro	2.09	1.78	1484	Univ Fed Minas Gerais	2.10	2.01
112	Empresa Brasileira Pesquisa Agropecuaria	0.39	0.35	275	Univ Fed Minas Gerais	1.85	1.59	1450	Univ Fed Rio de Janeiro	1.98	1.90
90	Univ Fed Minas Gerais	1.66	1.09	259	Univ Fed Rio Grande Sul	2.28	1.95	1066	Univ Estadual Paulista	1.63	1.55
87	Univ Fed Rio Grande Sul	2.61	1.77	246	Univ Estadual Paulista	1.66	1.37	980	Univ Fed Rio Grande Sul	1.85	1.80
78	Escola Paulista Med	2.50	1.70	140	Inst Oswaldo Cruz	1.67	1.51	490	Univ Fed Santa Catarina	1.71	1.66
69	Univ Estadual Paulista	1.06	0.60	136	Univ Fed Sao Carlos	1.77	1.73	485	Univ Fed Sao Carlos	1.55	1.49
69	Univ Brasilia	1.54	1.03	126	Ctr. Brasiliero Pesquisas Fis	2.97	2.45	436	Univ Fed Pernambuco	1.62	1.52
65	Univ Fed Pernambuco	1.73	1.20	126	Escola Paulista Med	2.54	2.22	434	Univ Fed Parana	1.92	1.61
60	Pontifica Univ Catolica Rio de Janeiro	1.50	1.13	125	Empresa Brasileira Pesquisa Agropecuaria	0.80	0.66	424	Univ Brasilia	1.57	1.49
36	Univ Fed Sao Carlos	2.19	1.77	112	Univ Fed Pernambuco	1.47	1.34	414	Empresa Brasileira Pesquisa Agropecuaria	1.15	1.02
35	Conselho Nacl Pesquisas	2.51	1.72	111	Pontifica Univ Catolica Rio de Janeiro	2.17	1.74	359	Inst Oswaldo Cruz	1.95	1.75
30	Ctr. Brasiliero Pesquisas Fis	1.97	1.38	110	Univ Fed Santa Catarina	1.75	1.52	354	Univ Fed Vicosa	0.80	0.76
29	Inst Nacl Pesquisas Amazonia	1.74	1.50	109	Univ Fed Fluminense	1.97	1.79	304	Univ Fed Fluminense	1.73	1.67
29	Univ Fed Fluminense	1.34	0.97	109	Univ Fed Parana	1.65	1.21	295	Univ Fed Bahia	1.75	1.65
27	Univ Fed Bahia	3.00	1.78	101	Univ Brasilia	1.77	1.61	260	Univ Fed Ceara	1.71	1.64
26	Conselho Nacl Desenvolvimento Cient & Tecn.	1.65	1.14	67	Inst Nacl Pesquisas Espacias	2.00	1.70	222	Univ Fed Santa Maria	1.66	1.62
26	Univ Fed Rio Grande Norte	1.62	0.87	62	Univ Fed Bahia	1.97	1.65	204	Univ Estado Rio de Janeiro	2.62	2.54
24	Inst Oswaldo Cruz	2.26	1.42	55	Univ Fed Vicosa	1.46	0.98	197	Univ Fed Rio Grande Norte	1.52	1.49

Table 19 says quite a bit about Brazilian research institutions:

- **University of Sao Paulo** is the clear "No. 1," with 2.5 times as many publications in SCI/SSCI as any other organization.
- Five universities stand forth next: **University of the State of Campinas, University Federale Minas Gerais, University Federale Rio de Janeiro, University of the State Paulista, and University Federale Rio Grande Sul.** For 2005, these range from about 1000-1700 publications in that year.

- Behind them, another tier of universities tops out at about half that publication level (approaching 500 per year).
- The top two research institutes – EMBRAPA (Empresa Brasileira Pesquisa Agropecuaria – 414 articles) and FioCruz (Inst Oswaldo Cruz – 359 articles) are publishing at rates in this tier. [EMBRAPA performing agricultural research and FioCruz, biomedical research]
- Stepping forward from 1985 to 1995 to 2005, the general view is of relative consistency in institutional positioning and active growth.
- Comparing standing in 1995 and 2005, some notable gainers in relative prominence are:
    - Four are newcomers to this "Top 20" list: Univ. Fed. Ceara, Univ. Fed. Santa Maria, Univ. Estado Rio de Janeiro, and Univ. Fed. Rio Grande Norte.
    - The Top 16 all carry forward from Top 20 positions in 1995. In terms of ratio of publications, these all increase anywhere from a factor of 2.5 to 6.4. Highest growth in SCI/SSCI publications is seen for Univ. Fed. Vicosa (6.4 times) and Univ. Fed. Minas Gerais (5.4 times).

We present two quality metrics in the form of weighted impact factor for "journals with impact factors" and also for "all journals." The former calculation is derived solely from those publications that appear in journals that have impact factors assigned. The 'All Journals' calculation also accounts for publications in journals without impact factors; for those journals, an impact factor of zero is used in the calculation.

Yet another caveat for this metric is that coverage of the 'Author affiliations' field in SCI/SSCI is sparse in 1985 (50%) and 1995 (70%). It must be noted that any of the papers without coverage in this field may be collaborative efforts, but not apparent because only the institution in the reprint address is credited the publication and, by extension, its journal's impact factor.

Note that the two metrics track closely. Being more selective, "journals with impact factors" score higher weighted impact factor values than do "all journals." However, the ratio for the Top 20 institutions for 2005 ranges narrowly from 1.02 to 1.19. The mean is 1.06; standard deviation of 0.04. The two variants correlate 0.985. We infer from this that use of one or the other would suffice.

Based on this, let's reflect on the "all journals" weighted impact factor. All but one of the Top 6 institutions (University of Sao Paulo and the tier of five prolific universities behind it) show weighted impact factors nearing 2 (The University of the State of Sao Paulo shows a notch lower at 1.55). Most of the remaining 14 institutions show at about 1.5 also. Two institutions are somewhat lower (EMBRAPA at 1.02 and Univ. Fed. Vicosa at 0.76). One is strikingly higher – the **University of the State of Rio de Janeiro** (2.54) – the highest of any institution by a considerable margin. This suggests attending to this university's work, even though its research output is less.

Table 20 shows a similar institutional tally updated to 2006. This conforms very closely to the pattern for 2005. Univ. Fed. Vicosa, particularly, continues its rapid climb in research activity.

Table 20 - Most Prolific Institutions (SCI/SSCI 2006)

# Recs 2006	Institution Name
4472	Univ Sao Paulo (USP)
1846	Univ Estadual Campinas (UNICAMP)
1708	Univ Fed Minas Gerais (UFMG)
1499	Univ Fed Rio de Janeiro (UFRJ)
1315	Univ Estadual Paulista (UNESP)
1027	Univ Fed Rio Grande Sul (UFRGS)
503	Univ Fed Santa Catarina
483	Univ Fed Sao Carlos (UFSCAR)
470	Empresa Brasileira Pesquisa Agropecuaria (EMBRAPA)
465	Univ Fed Parana UFPR
421	Univ Fed Pernambuco (UFPE)
420	Inst Oswaldo Cruz (FIOCRUZ)
412	Univ Brasilia
412	Univ Fed Vicosa (UFV)
336	Univ Fed Ceara
330	Univ Fed Fluminense (UFF)
292	Univ Estadual Rio de Janeiro
284	Univ Fed Santa Maria
264	Univ Fed Bahia (UFBA)
223	Univ Estadual Maringa
190	Univ Fed Rio Grande Norte
174	Univ Fed Uberlandia
168	Univ Fed Paraiba
159	Pontificia Univ Catolica Rio de Janeiro
151	Ctr Brasileiro Pesquisas Fis
148	Univ Fed Para
141	Univ Fed Goias
131	Inst Nacl Pesquisas Espaciais
123	Univ Estadual Londrina
105	Univ Fed Pelotas

Notes to Table 20: Based on 17965 SCI/SSCI publications with a Brazilian author for 2006; list cleaned in TechOASIS

Table 21 illustrates "profiling." This example case selects the 5 most prolific institutions shown in Table 20 for which to "breakout" selected additional information. Here we show the most frequent collaborating countries, most frequent SCI/SSCI Subject categories, and most popular journals.

Table 21 - Profile of 5 Prolific Brazilian Institutions
(SCI/SSCI 2006)

Institutions	Collaborating Countries	Subject Category	Journals
5 Most Prolific	Most Frequent	Most Frequent	Most Frequent
Univ Sao Paulo (USP)[4472]	USA [585]; France [169]; Germany [160]; UK [158]; Italy [102]	Biochemistry & Molecular Biology [266]; Neurosciences [210]; Pharmacology & Pharmacy [185]; Dentistry, Oral Surgery & Medicine [178]; Chemistry, Physical [170]	Br. J. of Med &Biological Research [75]; Brazilian Journal Of Physics [58]; Quimica Nova [50]; Physical Review D [45]; Revista De Saude Publica [45]
Univ Estadual Campinas (UNICAMP)[1846]	USA [154]; Italy [43]; UK [40]; France [40]; Spain [39]	Dentistry, Oral Surgery & Medicine [135]; Chemistry, Physical [110]; Biochemistry & Mol. Biol [95]; Physics, Condensed Matter [84]; Materials Science, Multidisciplinary [82]	Physical Review B [35]; Quimica Nova [34]; Journal Of The Brazilian Chemical Society [26]; Brazilian Journal Of Physics [20]; Arquivos De Neuro-Psiquiatria [17]
Univ Fed Minas Gerais (UFMG)[1708]	USA [240]; France [53]; UK [49]; Germany [43]; Canada [33]	Immunology [119]; Neurosciences [112]; Biochemistry & Molecular Biology [98]; Microbiology [93]; Pharmacology & Pharmacy [88]	Br. J. of Med &Biological Research [46]; Arquivos De Neuro-Psiquiatria [43]; Arquivo Br. De Medicina Veterinaria E Zootec. [42]; Memorias Do Instituto Oswaldo Cruz [25];
Univ Fed Rio de Janeiro (UFRJ)[1499]	USA [187]; UK [99]; France [79]; Germany [58]; Portugal [48]	Biochemistry & Molecular Biology [103]; Chemistry, Physical [69]; Physics, Multidisciplinary [68]; Microbiology [63];	Zootaxa [30]; Acta Crystallographica Section E-Structure Reports Online [25]; Acta Crystallographica Section C-Crystal Structure Communications [19];
Univ Estadual Paulista (UNESP)[1315]	USA [92]; France [51]; UK [50]; Germany [41]; Canada [38]	Veterinary Sciences [122]; Biochemistry & Molecular Biology [85]; Physics, Multidisciplinary [70]; Materials Science, Multidisciplinary [65];	Revista Brasileira De Zootecnia-Brazilian Journal Of Animal Science [43]; Arquivo Brasileiro De Medicina Veterinaria E Zootecnia [27];

Three points to note:
1. The content of such profiles can be easily customized to whatever fields the user wants.
2. Further breakouts are possible. For instance, one can quite readily extract the 585 articles on which USP researchers co-authored with US counterparts (the top row in Table 21) to explore "which Americans are working with which USP researchers on topic X."
3. Interactive versions of these capabilities are available to the user community via the TechOASIS software (described in Section 7).

Figure 7 explores another dimension – which institutions collaborate extensively? Here we map the 30 most prolific Brazilian research institutions for 2006 using TechOASIS software. This is based on extraction of authors' organizational affiliation (institution) from the SCI/SSCI records. SCI/SSCI provides affiliations for all the authors, but it does not link each author to a particular affiliation (no problem for this analysis). For instance, if a given paper were authored by 10 researchers affiliated with 3 institutions, we capture that there was collaboration among those 3 (no weighting by how many authors are affiliated with each). Figure 7 is based on such co-occurrence of author affiliations among the 17965 articles for 2006.

This and other TechOASIS maps of researcher networking included have several features in common:

- Nodes (shown as colored dots) represent each entity (here, institutions). The size of the dot roughly reflects the extent of activity (USP is the publication leader). As per the legend, lines connecting the dots reflect degree of interaction on a relative scaling.
- These are Multi-Dimensional Scaling ("MDS") representations. Put simply, the algorithm tries to locate entities that are more related closer together. However, for 30 entities, one would need a 30-dimensional representation for absolute accuracy. Our 2-dimensional representation is thus a rough representation.
- X axis and Y axis location in an MDS representation conveys no meaning. The map is useful in showing nearness among particular nodes.
- To better show relatedness, a Path-Erasing Algorithm is used. This allows one to render a representation with more or less links shown (as per the legend). Heavier lines between nodes represent greater relationship (one can think "correlation").
- These maps can be viewed interactively in TechOASIS, enabling a user to "dig down" to explore aspects of a node of particular interest (e.g., to identify particular researchers and their topical emphases at a given institution).

This map (Figure 7) shows considerable, moderate linkage. We don't see dominant partnering relationships. This suggests that Brazilian research organizations (especially universities) are quite open to collaboration. At the threshold for relative connectivity used, we see no links for USP, but were we to relax this threshold, we would.

Going beyond such overall maps, we suggest that users apply these tools to probe particular relationships of interest. For instance, if one is considering a teaming relationship on a particular research theme, consider separating out the leading research groups (i.e., create a sub-dataset in TechOASIS). Then, map the established ties within that research arena, particularly with US institutions.

Figure 7 - Collaboration Map among 30 most Prolific Institutions

(SCI/SSCI 2006) Links reflect amount of collaboration relative to total papers for the institution

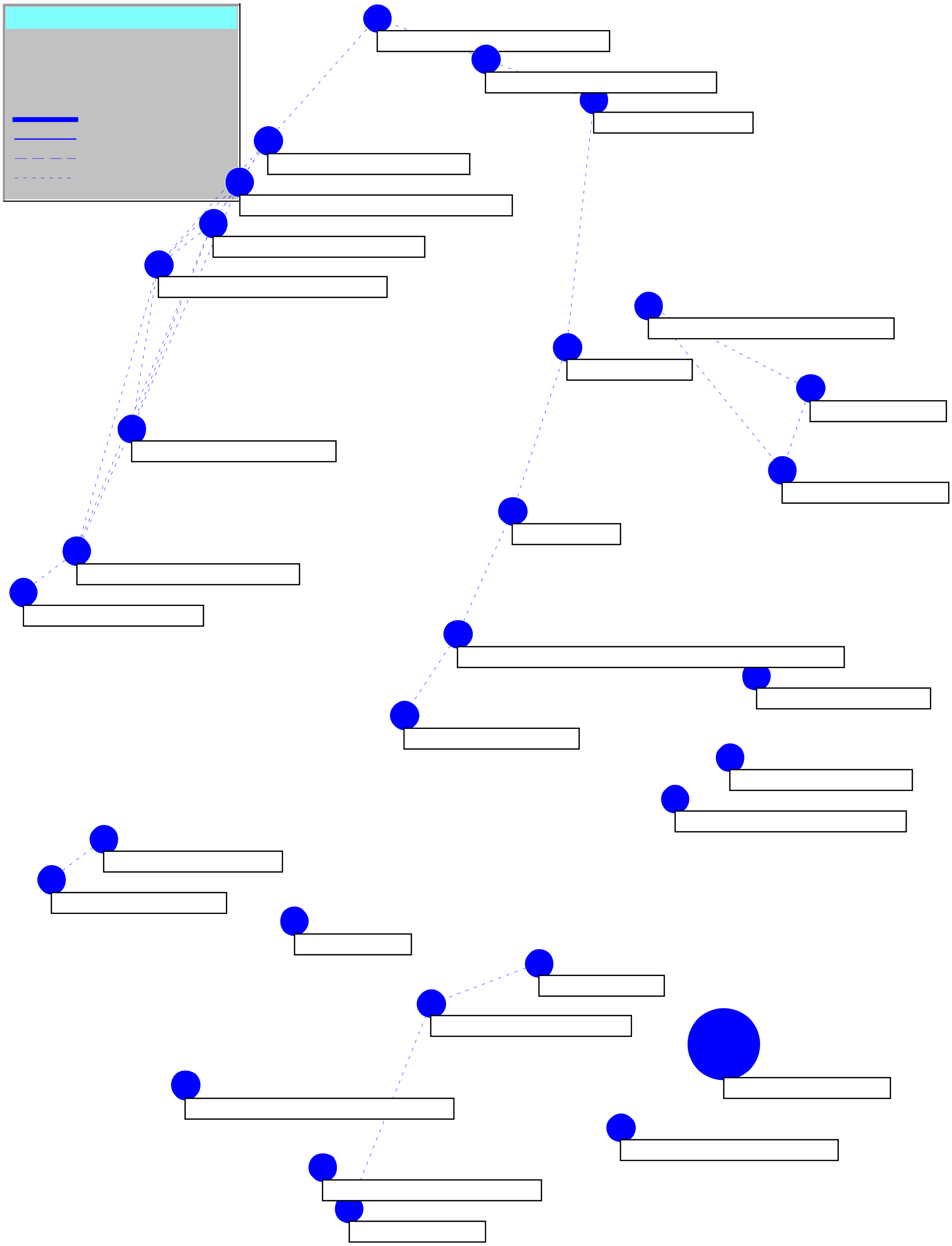
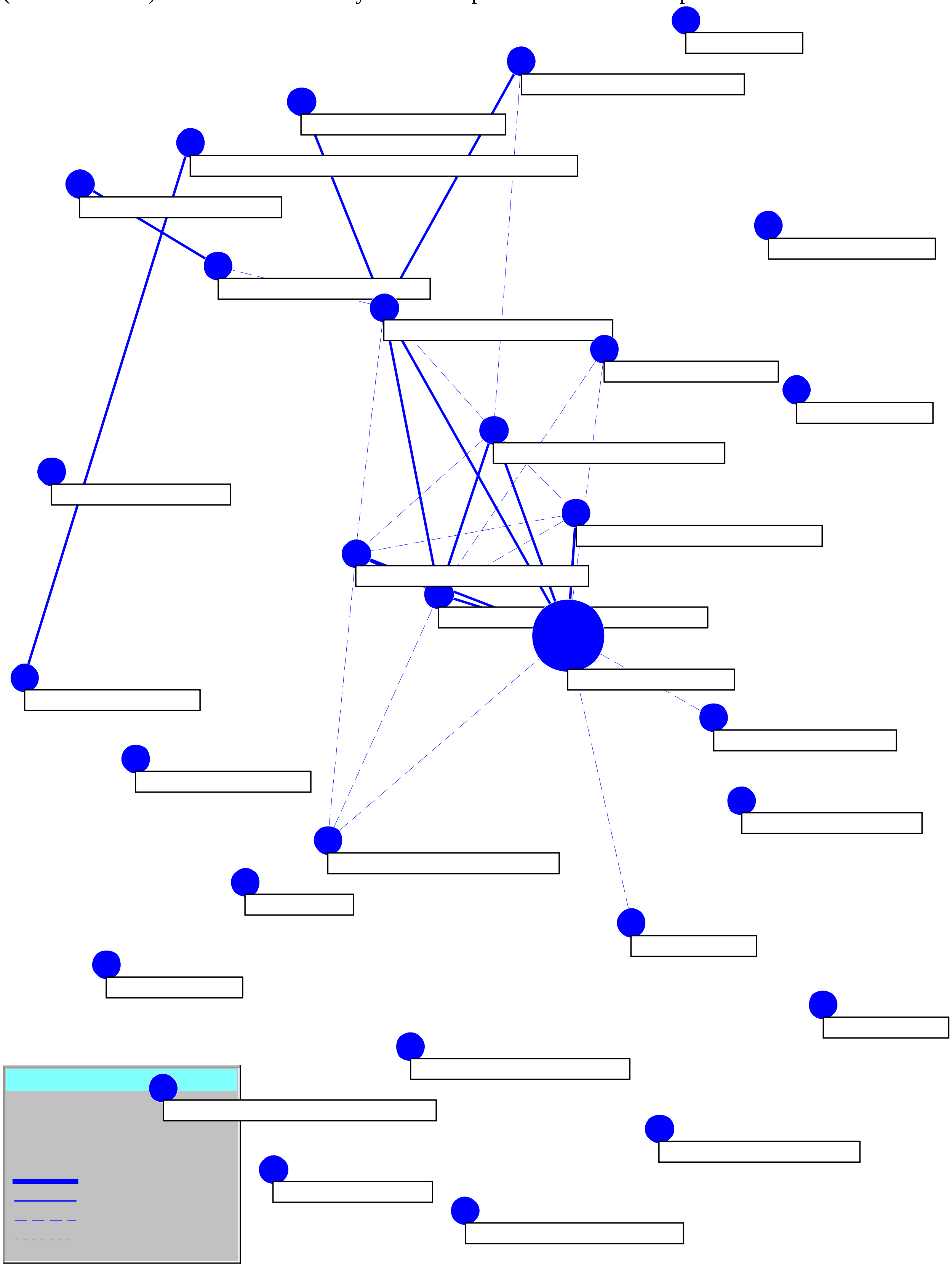


Figure 8 provides a different networking perspective. For this, we took two- and three-word Text Dicer phrases, then removed stopwords. We next created a cross-correlation map based on such phrases occurring two or more times in the 17965 SCI/SSCI articles from 2006. Contrast this type of map, which shows common use of terminology, with Figure 7, based on co-authoring of specific documents.

The cross-correlation mapping, Figure 8, shows the overall degree of shared research interests. EMBRAPA emphasizes agricultural research; seeing it linked to Univ. Fed. Vicosa suggests that this might be an agriculturally oriented university counterpart. Note for these maps that the threshold for depicting links is at our discretion; there is no right way. Were one to set the threshold low, imagine that most large research institutions (largely universities) would show common interests with "everyone." In Section 7 we illustrate applying mapping to more focused network analyses.

Figure 8 - Institution-Phrase Cross-Correlation Map
(SCI/SSCI 2006) Links reflect similarity of abstract phrases in institutional publications



5.4 Countries

Table 22 shows the countries collaborating most with Brazil, and the apparent rank as collaborator for that year. Changes in rank across the 10-year time slice are shown in the 'Delta' columns. Because country coverage information is extremely sparse in 1985 and 1995, much caution needs to be used when comparing a country's raw publication counts to the number of Brazilian publications.[19] Due to these data considerations, we don't make too much of the delta in extent of collaboration over these time periods.

Green shading indicates a country has moved up in rank as collaborator, red indicates a downward move. The ++ for Austria and Norway indicates that there were no apparent collaborative efforts with Brazil in 1985.

Table 22 - Collaborating Countries for Selected Years

1985 Rank	Countries	# Rec 1985	1985-1995 Delta	1995 Rank	Countries	# Rec 1995	1995-2005 Delta	2005 Rank	Countries	# Rec 2005
	Brazil	2318			Brazil	5341			Brazil	16936
1	USA	171	0	1	USA	765	0	1	USA	1965
2	France	67	0	2	France	279	0	2	France	694
3	Germany	38	1	3	UK	265	0	3	UK	671
4	UK	35	-1	4	Germany	186	0	4	Germany	645
5	Canada	26	1	5	Italy	174	1	5	Canada	372
6	Italy	22	-1	6	Canada	138	5	6	Argentina	343
7	Argentina	20	4	7	Spain	113	-2	7	Italy	324
8	Chile	9	19	8	Russia*	82	-1	8	Spain	296
8	Switzerland	9	-1	9	Switzerland	77	5	9	Netherlands	211
10	Japan	8	4	10	Belgium	71	3	10	Japan	207
11	Spain	7	-4	11	Argentina	70	0	11	Portugal	200
11	Sweden	7	10	11	Portugal	70	-4	12	Russia	177
13	Denmark	6	-3	13	Japan	67	17	13	Australia	161
14	Australia	5	3	14	Netherlands	65	15	14	China	148
14	Belgium	5	2	15	Poland	52	1	15	Mexico	145
14	India	5	5	16	Mexico	48	0	16	Sweden	136
17	Israel	4	-5	16	Sweden	48	7	17	India	134
17	Netherlands	4	++	18	Austria	37	8	18	Chile	125
17	Poland	4	++	18	Norway	37	-10	19	Switzerland	121
20	Colombia	3	-7	20	Denmark	36	-10	20	Belgium	118
			7	20	Finland	36				

*Russia's rank as collaborator in 1995 is compared to that of the USSR in 1985.

[19] The SCI/SSCI 'Analyze' was used to determine the number of publications for each country using the Author Affiliations and the Reprint Address fields. There is only one reprint address per record, so that can't be used to identify collaboration. So, if the record does not have Author Affiliations, it is not possible to identify collaborators.

The USA is Brazil's leading collaborative partner (on about 12% of its SCI/SSCI articles). This implies that established Brazilian-American research ties offer a fine resource upon which to build additional partnerships. The USA leads by a ratio of almost 3:1 over second-place France. However, given the relative size of the American and French research enterprises, this suggests roughly proportional degree of outreach by each to Brazil. Much the same could be said for British and German linkage, as well as Canadian. Scanning the list of leading collaborators, Brazil shows an affinity for the Western OECD research powers, relative to Japan, for instance. Language appears a secondary factor, as Portugal shows quite significant interaction, given its smaller research enterprise. Proximity shows relatively modestly, with Argentina a notable partner.

What is Brazil's standing in the ranks of its major research partner countries? We conducted searches in SCI/SSCI for each of Brazil's most frequently collaborating countries in the year 2006. We used the Web of Science 'Analyze' function to determine Brazil's role as their collaborator. Table 23 lists Brazil's most frequent collaborating countries in the most recent complete year (2006) preceded by the number of collaborative papers published – a one-year update of the last column of Table 22. The last column shows Brazil's position in the rankings of each country's collaborators.

Table 23 - Brazil's Rank as Collaborating Country

# Papers 2006	Country	Brazil's Rank as Collab.
17965	**Brazil**	
2049	USA*	16
732	France	16
680	UK	27
654	Germany	23
395	Spain	16
393	Italy	20
353	Canada	17
345	Argentina	3
267	Portugal	7
216	Japan	22
213	Netherlands	23
173	Australia	22
165	Mexico	7
163	Russia	25
163	Switzerland	27
147	Chile	7
146	Sweden	24
136	China	22
134	Belgium	25
131	India	17

*Brazil's rank as USA's collaborator based on a sample of 100,000 records – as per the limit of the SCI/SSCI Analyze function.

Table 23 indicates that Brazil is not a major presence in the research universe of its leading collaborating countries. The USA, for instance, shows more co-authoring with 15 other nations, as does France. Brazil is most prominent as a partner for other Latin American countries – Argentina, Mexico, and Chile – and for Portugal with whom it shares colonial heritage and language.

What are the major research thrusts of international collaborations? Table 24 profiles the 5 most frequent collaborating countries from Table 23. It shows the most frequent themes from the SCI/SSCI taxonomy (see Section 6) and the journals in which collaborative research is most often published.[20]

Table 24 shows interesting differences. Brazil's collaborative emphases vary considerably. Life and biomedical research show prominently in Brazilian co-authored papers with the USA, UK, and Spain, way more than with France and Germany. Computing cluster topics show collaboration with four leading partner countries, but not with Spain (as a "Top 5" topic). Astronomy seems notably lacking in USA collaborations relative to European ones. We don't want to make too much of these differences as the counts are often close (note the top French clusters).

In terms of journals, all the collaborations show most prominently in leading physical science sources.

Again, we think the greater value lies beneath this overall veneer. One can use the analytical tools to probe particular research themes more deeply. For a given research theme, it can be very revealing to then break out the key research organizations, their sub-topical emphases, leading researchers, and international collaborators (see Section 7).

[20] The TechOASIS data file was synchronized to reflect clustering results obtained from the CLUTO/SpaceTree software, and then a TechOASIS script was used to generate the profile in Table 24.

Table 24 - Profile of Leading Country Collaborations with Brazil

Collaborating Country	Level 4 Taxonomy Cluster Themes	Journals
SCI/SSCI 2006 [# Pubs w/ Brazil]	**Most Frequent [# Pubs w/ Brazil]**	**Most Frequent [# Pubs w/ Brazil]**
USA [2049]	Microbiology, Infectious Diseases & Treatments [449]; Diagnosis and Treatment of Chronic Diseases [395]; Computer Hardware, Networks, and Algorithms [234]; Molecular & Cell Biology; Biophysics [220]; Particle Physics & Field Effects [206]	Physical Review B [35]; Physical Review Letters [34]; Physical Review D [26]; Physics Letters B [18]; Astrophysical Journal [17]
France [732]	Computer Hardware, Networks, and Algorithms [110]; Astronomy & Astrophysics [98]; Mathematical Modeling of Physical Systems & Phenomena [98]; Industrial Chemistry & Earth Sciences [97]	Physical Review Letters [31]; Astronomy & Astrophysics [24]; Physical Review D [15]; Physics Letters B [13]
UK [680]	Microbiology, Infectious Diseases & Treatments [127]; Computer Hardware, Networks, and Algorithms [101]; Diagnosis and Treatment of Chronic Diseases [86]; Organic Chemistry and Crystallography [73]; Astronomy & Astrophysics [67]	Acta Crys. E-Struct Rpts. Online [26]; Physical Review Letters [24]; Acta Crys. C-Crystal Struct Commun [20]; Physical Review D [17]; Physics Letters B [13]
Germany [654]	Astronomy & Astrophysics [94]; Industrial Chemistry & Earth Sciences [94]; Computer Hardware, Networks, and Algorithms [85]; Particle Physics & Field Effects [79]; Diagnosis and Treatment of Chronic Diseases [75]	Physical Review Letters [29]; Acta Crys. E-Struct Rpts. Online [28]; Astronomy & Astrophysics [16]; Physical Review D [14]; Physics Letters B [13]
Spain [395]	Industrial Chemistry & Earth Sciences [63]; Microbiology, Infectious Diseases & Treatments [61]; Materials Science [51]; Diagnosis and Treatment of Chronic Diseases [47]; Particle Physics & Field Effects [46]	European Physical Journal C [10]; Astronomy & Astrophysics [10]; Physica B-Condensed Matter [6]; Physics Letters B [5]; IEEE Transactions On Nuclear Science [5]

What effect does international collaboration have on the number of citations that a paper receives? We used TechOASIS to group each of 16299 SCI/SSCI records from the downloaded Brazil samples for 1995 and 2000 into one of two categories: a) 5762 Brazil papers that list an author's institution from another country, and b) 10537 records which list only Brazilian institutions. Table 25 shows that international collaboration has considerable quality implications. On each of three metrics, international jointly authored papers receive somewhere between two and four times as many citations.

Table 25 - Impact of International Collaboration on Citations Received

	Brazil & Other Countries	Brazil Only	Ratio Collab/ Brazil Only
Total Articles in Sample	5762	10537	0.55
Median # Citations of All Articles	8	3	2.67
Median # Citations received for 10 most cited	670	168	3.99
Median # Citations received by most Cited 5%	73	33	2.21

5.5 Brazil/USA Comparison

We next compare the relative research thrusts of Brazil to those of the United States. These comparisons could help identify opportunities for collaboration.

To measure this, we used general topical categories (Subject Categories for SCI/SSCI; Classification Codes for EC) available from the database's website. The number of publications in each category was divided by the total number of publications to determine what percentage of the country's publication output falls into a particular category. We compared these percentages for Brazil and the USA to find topic areas where this difference is pronounced.

For the SCI/SSCI subject category comparison, a sample of 25355 records with at least one Brazilian author and published in 2006-2007 (partial) was compared to a sample of the most recent 100,000 publications with a USA author published in 2007.

Table 26 lists the SCI/SSCI Subject categories which are more prevalent in Brazilian papers than in those published by the USA. Subject categories in bold font are those in which Brazil leads the USA in publication counts.

Table 26 - SCI/SSCI Subject Categories – Brazil's Relative Emphases

	Difference	Brazil (2006-07)		USA (2007 Sample)	
Subject Category	**% Brazil -% USA**	**Records**	**% of 25355**	**Records**	**% of 100000**
Veterinary Sciences	2.56%	941	3.71%	1147	1.15%
Dentistry, Oral Surgery & Medicine	**2.37%**	**736**	**2.90%**	**536**	**0.54%**
Zoology	2.07%	767	3.03%	960	0.96%
Physics, Multidisciplinary	1.97%	822	3.24%	1271	1.27%
Parasitology	**1.66%**	**473**	**1.87%**	**207**	**0.21%**
Agriculture, Multidisciplinary	**1.65%**	**485**	**1.91%**	**261**	**0.26%**
Tropical Medicine	**1.61%**	**441**	**1.74%**	**134**	**0.13%**
Chemistry, Physical	1.59%	918	3.62%	2035	2.04%
Entomology	1.53%	527	2.08%	550	0.55%
Chemistry, Analytical	1.52%	691	2.73%	1201	1.20%
Biology	1.47%	560	2.21%	738	0.74%
Physics, Condensed Matter	1.41%	676	2.67%	1255	1.26%
Engineering, Chemical	1.22%	496	1.96%	737	0.74%
Agriculture, Dairy & Animal Science	1.10%	389	1.53%	430	0.43%
Food Science & Technology	1.10%	506	2.00%	895	0.90%

Notice that Brazil leads the USA in raw publication counts in four of these Subject Categories even though the sample size analyzed for Brazil is smaller by nearly a factor of four! Also observe that ten of the fifteen top subject categories represent life-sciences, including all four of

the categories where Brazil leads the United States in publication counts. No social sciences appear in this list.

Table 27 lists those Subject Categories which appear more times, on average, for publications by the USA.

Table 27 - SCI/SSCI Subject Categories – USA's Relative Emphases

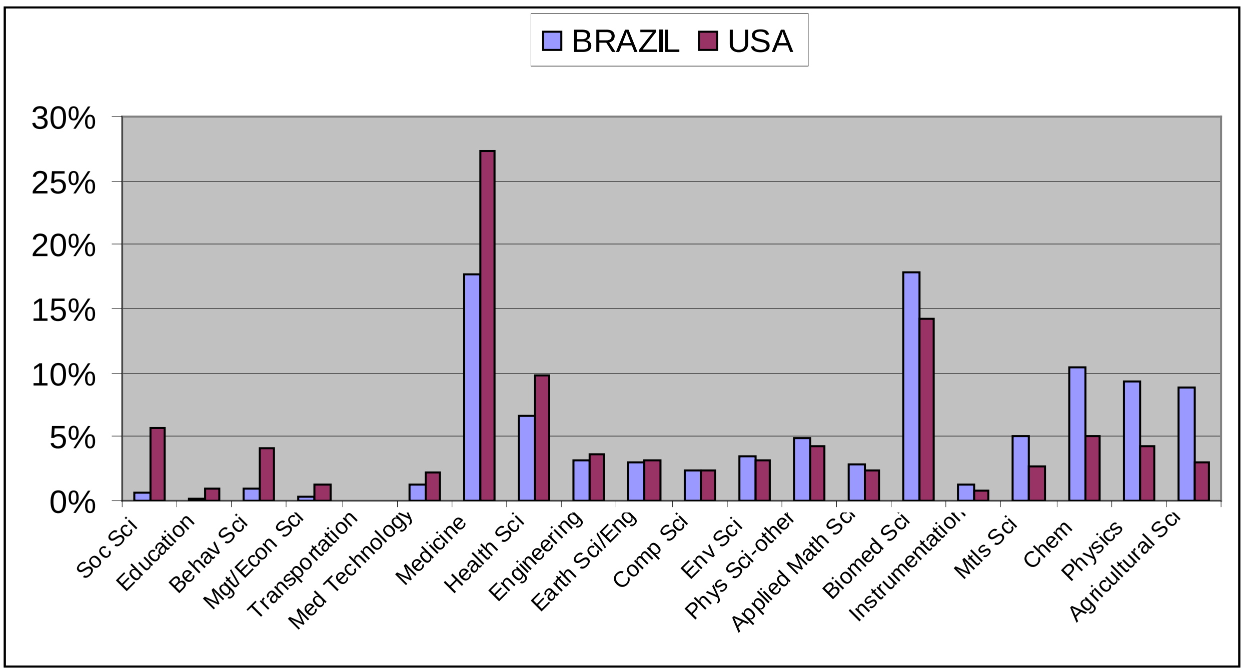
SCI/SSCI Subject Category	Difference	Brazil (2006-2007)		USA (2007 Sample)	
	% Brazil -% USA	Records	% of 25355	Records	% of 100000
Oncology	-2.28%	273	1.08%	3353	3.35%
Cell Biology	-1.72%	396	1.56%	3285	3.29%
Biochemistry & Molecular Biology	-1.65%	1216	4.80%	6442	6.44%
Economics	-1.13%	59	0.23%	1367	1.37%
Medicine, General & Internal	-1.09%	86	0.34%	1429	1.43%
Multidisciplinary Sciences	-1.07%	161	0.64%	1704	1.70%
Cardiac & Cardiovascular Systems	-1.05%	201	0.79%	1842	1.84%
Radiology, Nuclear Medicine & Medical Imaging	-0.94%	187	0.74%	1682	1.68%
Engineering, Electrical & Electronic	-0.88%	462	1.82%	2699	2.70%
Psychology, Clinical	-0.84%	26	0.10%	940	0.94%
Hematology	-0.82%	165	0.65%	1469	1.47%

Once again, we see a high incidence of life sciences categories, but the USA list is more concentrated on clinical medicine than Brazil's, which tend to be more agricultural and animal science oriented. We also note that two social science categories, Economics and Clinical Psychology, are more prominent in US research.

There is no standard Institute for Scientific Information (ISI, the provider of SCI and SSCI) hierarchy by which to consolidate the 245 Subject Categories into fewer "mega-fields." In conjunction with an ongoing project for the U.S. National Academies, we have derived such a classification.

Figure 9 compares the prevalence of 20 "mega-fields" in our Brazilian dataset to a general USA sample set used in the National Academies project.[21] The mega-fields are ordered to show those with greatest Brazilian emphasis relative to the USA to the right. These are research domains in which the USA might particularly look toward Brazilian research for novel contributions. Agriculture leads, followed by the two main physical sciences. The Figure also prominently shows the extensive Brazilian attention to medical and biomedical research, but these are also the dominant US research areas. At the other extreme, some areas where Brazil's SCI/SSCI publications suggest both lesser emphasis and lesser research output are the Social and Behavioral Sciences. Table 28 shows the underlying frequencies, ordered from most to fewest Brazilian articles.

Figure 9 - Relative Brazilian/US Research Emphases (SCI/SSCI)[22]



[21] This is a fused set of four one-week samples of US-authored publications from Web of Science (including SCI, SSCI, and AHCI – Arts and Humanities Citation index). Three weeks are from 2005 (March 30, May 14, and June 11), with one week from 2006 (August 15). We leave out one mega-field – Literature & Humanities – in that it is not of high interest and our Brazilian data do not sample AHCI.

[22] Data are normalized in two stages. First, the number of articles associated with a given mega-field is divided by the total number of articles. Second, because, articles can be linked to more than one Subject Category, and potentially more than one mega-field (a group of Subject Categories), the country total is rescaled to total 100% to facilitate comparison of relative emphases.

Table 28 - Brazil and USA Articles per Mega-Field (SCI/SSCI)

Mega-Field	BRAZIL	USA
Biomed Sci	4349	4738
Medicine	4287	9072
Chem	2536	1655
Physics	2256	1406
Agricultural Sci	2145	972
Health Sci	1605	3241
Mtls Sci	1220	881
Phys Sci-other	1179	1404
Env Sci	846	1072
Engineering	751	1194
Earth Sci/Eng	742	1052
Applied Math Sci	683	776
Comp Sci	590	789
Med Technology	301	729
Instrumentation	293	250
Behav Sci	222	1337
Soc Sci	160	1895
Mgt/Econ Sci	70	400
Education	32	322
Transportation	6	17
TOTAL	17960	27890

For another perspective we looked at the leading EC Classification Codes for the USA and Brazil.[23] The Brazil sample consisted of 25333 records for papers published from 2003 to 2007 (partial as of 6/12/2007). The sample for USA consisted of 29194 records for papers published so far in 2007. The Brazil sample includes multiple years to obtain a robust number of publications for analysis.

These lists were compared for the USA and EC samples described above, and the relative emphases of the two countries are compared in the following two tables.

[23] In on-line searching of EC, the list of classification codes associated with a query is automatically generated by the database and displayed with your search results.

Table 29 - EC Classification Codes – Brazil's Relative Emphases

EC Classification Code	Difference	Brazil 2003-2007(partial)		USA 2007(partial)	
	% Brazil - % USA	Records	% of 25333	Records	% of 29194
Chemical Operations	6.8%	4226	16.7%	2883	9.9%
Chemistry	5.1%	2770	10.9%	1699	5.8%
Light/Optics	4.7%	3536	14.0%	2704	9.3%
Inorganic Compounds	4.6%	3517	13.9%	2705	9.3%
Chemical Reactions	4.6%	4484	17.7%	3825	13.1%
Electricity: Basic Concepts and Phenomena	4.0%	3052	12.0%	2351	8.1%
Mathematics	3.8%	3607	14.2%	3035	10.4%
Control Systems	3.2%	2218	8.8%	1609	5.5%
Physical Properties of Gases, Liquids and Solids	3.0%	3472	13.7%	3131	10.7%
Organic Polymers	2.8%	1759	6.9%	1208	4.1%
Atomic and Molecular Physics	2.6%	3016	11.9%	2724	9.3%
Artificial Intelligence	2.5%	1682	6.6%	1199	4.1%
Chemical Agents and Basic Industrial Chemicals	2.2%	1774	7.0%	1388	4.8%
Thermodynamics	2.2%	1605	6.3%	1195	4.1%
Strength of Building Materials; Mechanical Properties	2.2%	1242	4.9%	787	2.7%
Algebra	2.2%	1327	5.2%	899	3.1%
Steel	2.0%	675	2.7%	189	0.6%
Organic Compounds	2.0%	3940	15.6%	3964	13.6%

Chemical topics appear to be emphasized more, on average, in Brazilian papers than in those published by USA institutions. Brazil's emphases in the 'Control systems,' 'Steel,' and 'Strength of Building Materials' categories may be an indicator of Brazil's industrial efforts.

Table 30 - EC Classification Codes - USA's Relative Emphases

EC Classification Code	Difference	Brazil 2003-2007(partial)		USA 2007(partial)	
	% Brazil - % USA	Records	% of 25333	Records	% of 29194
Materials Science	-6.0%	301	1.2%	2091	7.2%
Biological Materials and Tissue Engineering	-4.0%	1586	6.3%	2994	10.3%
Biology	-3.6%	1163	4.6%	2383	8.2%
Nanotechnology	-3.6%	124	0.5%	1185	4.1%
Medicine and Pharmacology	-2.4%	989	3.9%	1850	6.3%
Biomedical Engineering	-2.0%	569	2.2%	1235	4.2%
Systems Science	-1.8%	93	0.4%	642	2.2%
Atmospheric Properties	-1.5%	616	2.4%	1154	4.0%
Biology and Biochemistry	-1.0%	320	1.3%	653	2.2%

Biology, medicine, and nanotechnology appear to be emphasized more in EC-indexed publications by the USA. Brazil's table of emphases includes six categories where the difference is 4.0% or greater. Conversely, if one considers the ratio of percentages, Table 29 finds several areas where the relative USA emphasis is very dominant (e.g., Nanotechnology, Systems Science).

Again, we point the interested user to the interactive tools available to probe particular topical areas of Brazilian R&D (see Section 7).

6. Taxonomies – Document Clustering

This section presents the results of a document clustering approach to determine pervasive technical themes of Brazil's research. The CLUTO software used for the clustering (http://glaros.dtc.umn.edu/gkhome/views/cluto) allows the user to specify the number of clusters to create. For this study, we generated 256 Fuzzy clusters based on words and phrases taken from the Titles and Abstracts of records downloaded from the SCI/SSCI and EC databases. This section presents two taxonomies based on clustering results derived from:

- 17965 SCI/SSCI records for Brazil papers published in 2006
- 21753 EC records for Brazil papers published between 2003 and February, 2007

Because the boundaries that divide disciplines of science are not clearly defined, scientific research papers may not fit into one single category (or cluster). If an individual record has terms that match those associated with 2 (or more) of the 256 clusters created, the fuzzy clustering schemes will include the record everywhere the algorithm has determined a fit.

Note that the resulting taxonomy categories are named by us. They reflect human judgment on the prevailing emphases based on frequently occurring title and abstract terms; prominent SCI/SSCI Subject Categories or EC Class Codes; and prominent keywords.

<u>SCI/SSCI Taxonomy Results</u>

Figure 10 shows the first four levels of the hierarchical taxonomy from SCI/SSCI, with each cell in the matrix representing a technical category.

There are four columns shown in the SCI/SSCI taxonomy diagram. Each column represents a level of the hierarchy. The highest level (1) is the left-most column, and the lowest level (4) is the right-most column. The number preceding each category heading is the number of records assigned by the algorithm to the category.

Note that the number of records used to create the taxonomy is not simply the sum of the number of records for all clusters at a given level of the taxonomy diagram; nor is the number of records for a node at level 1 the simple sum of the number of records for its child nodes at level 2. The apparent discrepancy is the result of records that overlap two or more of the fuzzy clusters created by the algorithm.

The number of overlapping records at each level of the taxonomy can be determined by adding the record totals shown for all clusters at a given level, then subtracting the number of records used for the analysis. For example, the number of overlapping records at level 1 is:
(9321+10369) – 17965 = 1725 Records, or 9.6% overlap.

General observations will be made about the categories in levels 1-3 to spotlight points of interest. The 16 categories in level 4 will be discussed individually in the order they appear (top to bottom) in the taxonomy diagram (Figure 10).

Figure 10 - SCI/SSCI Taxonomy

Based on Titles and Abstracts from 17965 records for 2006

Level 1	Level 2	Level 3	Level 4
(9321) Physical Sciences/ Mathematics	(5246) – Mathematics & Physics	(3590) – Mathematics & Computer Science	(2133) Computer Hardware, Networks, and Algorithms
			(1763) - Mathematical Modeling of Physical Systems and Phenomena
		(2034) – Physics	(333) - Astronomy & Astrophysics
			(1733) - Particle Physics & Field Effects
	(4988) – Chemistry & Materials Science	(2024) – Materials Science	(1770) - Properties and Synthesis of Materials
			(335) - Thin Films and Surface Effects
		(3229) - Chemistry	(990) - Organic Chemistry and Crystallography
			(2343) – Analytical Chemistry & Earth Sciences
(10369) Biomedical/ Environmental Sciences	(3976) - Biological/Agricultural Research	(2280) - Agricultural & Veterinary Sciences	(1696) - Soils and Crops
			(637) - Dairy and Livestock; Veterinary Medicine
		(1858) - Ecological and Zoological Research	(1455) - Plant and Animal Sciences
			(681) - Taxonomy and Evolutionary Biology
	(7326) - Clinical Medicine/Pharmacology	(5121) - Human Patient Diseases	(2887) – Microbiology & Infectious Diseases
			(2708) – Diagnosis and Treatment of Human Patient Diseases
		(2875) - Cell Biology & Neuroscience	(1678) - Molecular & Cell Biology; Biophysics
			(1374) – Pharmacology & Drug Research

Comparisons are also made to the taxonomy results from China and India samples as reported by Kostoff et al.(to appear). The taxonomy diagrams for these countries are included in the appendix of this report.

The first level of Brazil's SCI/SSCI taxonomy is divided into general categories of Physical Sciences/Mathematics and Biomedical/Environmental Sciences, and suggests a somewhat stronger emphasis on the Biomedical/Environmental research. The records that overlap into both categories include, for example, health studies based on mathematical models. At this first level, the character of Brazilian research already begins to distinguish itself from China and India, both of which place stronger emphasis on physical sciences.

At Level 2, the Physical Sciences/Mathematics category divides generally along lines of Mathematics/Physics and Chemistry/Materials. Records which overlap these two categories generally share terms related to atoms, molecules, and measurements at the atomic scale. In other country studies, the corresponding four Level 2 clusters constitute the major "Themes."

The Biomedical/Environmental Sciences category divides into Biology/Agricultural and a considerably stronger emphasis on Medical/Pharmacological research. Overlap in these categories seems to reflect, particularly, converging interests in evolutionary biology and treatments for infectious diseases.

At Level 3, a strong emphasis on research in Human patient diseases emerges as a major thrust of Brazil's research (5121 articles associated here). Comparing SCI/SSCI Level 3 categories to China and India again spotlights Brazil's somewhat greater life and biomedical science emphases (but note that all three of these large, national research enterprises show considerable activity in many research arenas). In the physical sciences arenas, research concentrations in Math/Computer Science and Chemistry stand forth at Level 3.

For Level 4 we provide two tools to help gain a sense of "what's happening." Figure 11, for SCI/SSCI, and Figure 13, for EC, visualize the degree of overlap (shared records) among the respective 16 clusters within this level. These add to the Figure 10 and Figure 12 information on hierarchical relationships between Level 4 and the levels above. In the text we describe each cluster's content in brief, point to key international collaborators in this research area, and note commonalities with other Level 4 clusters. As users seek to identify key research organizations or leading researchers, we hope these "fuzzy" indications assist in exploring related interests. Section 7 suggests interactive ways to probe the data further in pursuit of one's particular interests.

Level 4

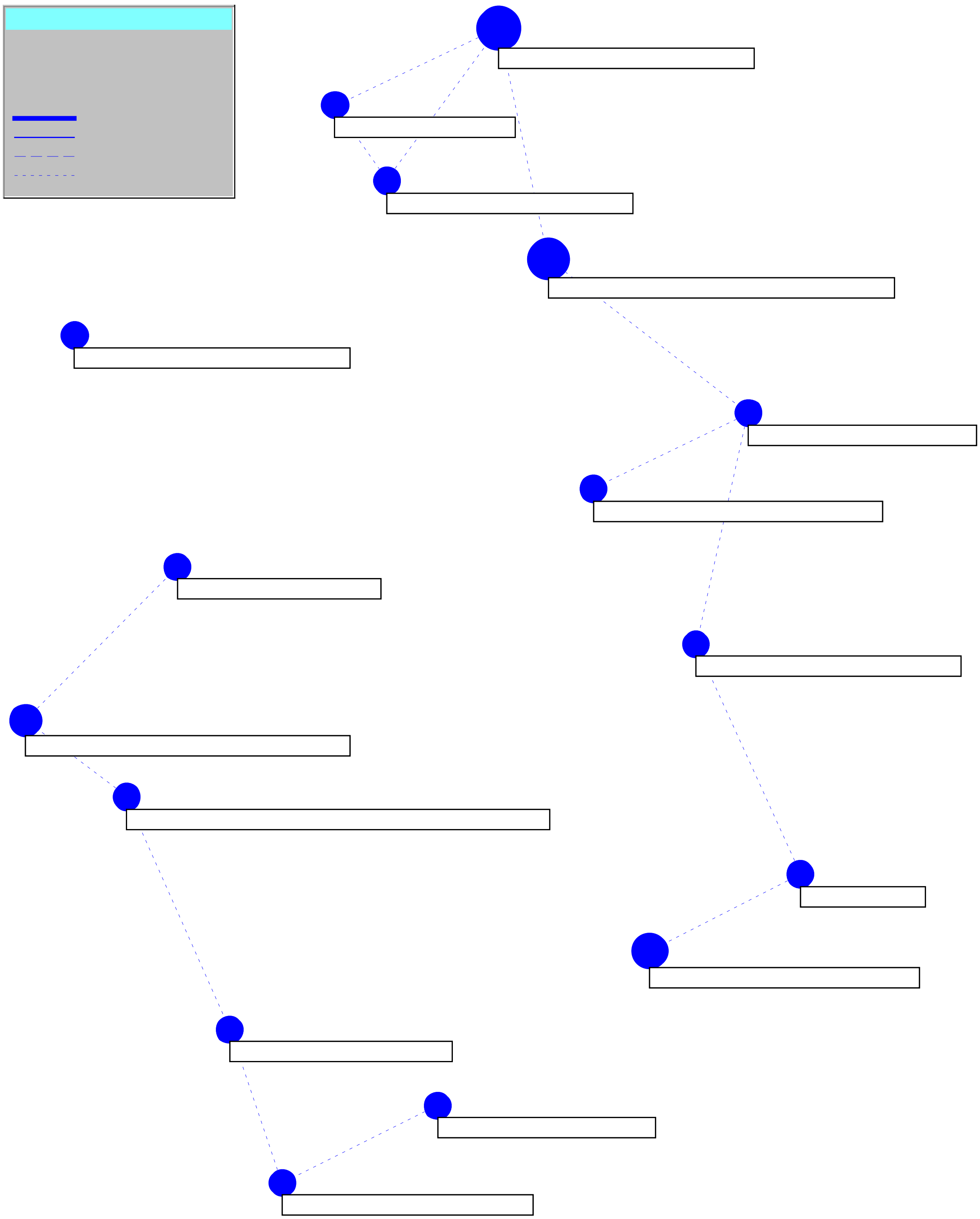
- Computer Hardware, Networks, and Algorithms-(2133 Records)
    - Focuses on Electrical Engineering, computer and communications networks and optimization algorithms.
    - USA, France, and UK are Brazil's major collaborators
    - Overlaps *Astronomy & Astrophysics* and *Mathematical Modeling* categories
- Mathematical Modeling of Physical Systems and Phenomena-(1763 Records)
    - Includes research in computer imaging, fluid and statistical mechanics systems

    - USA and France are the most frequently collaborating countries
    - Overlaps *Computer Hardware, Networks and Algorithms* and *Particle Physics & Field Effects* categories
- Astronomy & Astrophysics-(333 Records)
    - Smallest category at this level of the taxonomy
    - Focus is observation-oriented and includes photometry & object detection
    - USA, France, and Germany are leading collaborators
    - Overlap with *Computer Hardware* category
- Particle Physics & Field Effects-(1733 Records)
    - Focuses on properties of elementary particles and electromagnetic fields
    - USA is the most frequent collaborator by far
    - Overlaps *Mathematical Modeling* and *Properties and Synthesis of Materials* categories
- Properties and Synthesis of Materials-(1770 Records)
    - Includes nanomaterials, lenses, polymers, ceramics, and compounds used for dentistry and oral surgery.
    - USA is the most frequent collaborator by a wide margin
    - Overlaps *Particle Physics & Field Effects* and *Thin Films and Surface Effects*
- Thin Films and Surface Effects-(335 Records)
    - Focuses on deposition methods and micro- and nano-scale measurements
    - USA, France, and Germany are the major collaborators
    - Overlaps *Properties and Synthesis of Materials*
- Organic Chemistry and Crystallography-(990 Records)
    - Chemical bonds, ligands, and carbonyl compounds are main areas of interest
    - UK and Germany are the largest collaborators, USA is third
    - Does not overlap strongly with other clusters
- Analytical Chemistry & Earth Sciences-(2343 Records)
    - Major research thrusts are gas & liquid chromatography, spectroscopy, and sensors
    - USA, France and Germany are major collaborators
    - Overlaps with *Soils and Crops*
- Soils and Crops-(1696 Records)
    - Soil chemistry, crops, food science, and environmental impact of agriculture are major themes of this category
    - USA, France, Spain, and Germany are frequent collaborators
    - Records that focus on environmental impact overlap with *Analytical Chemistry & Earth Sciences*
    - Studies on plants at the cellular level are the cause for overlap with *Molecular & Cell Biology; Biophysics*
- Dairy and Livestock; Veterinary Medicine-(637 Records)
    - Terms which describe the diet and weight of livestock animals are spotlighted.
    - A large portion of this research is published in Veterinary & Animal Science journals
    - USA, France, Germany, and UK are the major collaborators
    - Some records that focus on endocrinology overlap with *Pharmacology & Drug Research*

- Plant and Animal Sciences-(1455 Records)
  - Brazil appears to emphasize research in this area far more than do either India or China.
  - Zoology, entomology, ecology, and marine & freshwater biology are covered.
  - USA, France, Germany, and UK are frequent collaborators
  - Overlap with *Microbiology & Infectious Diseases* appears to occur because abstracts for both these areas contain terms which refer to 'species' and 'populations' generally.
  - Research on species populations and ecologies overlaps with the *Taxonomy and Evolutionary Biology* category
- Taxonomy and Evolutionary Biology-(681 Records)
  - This category is not found at this level in taxonomies for either India or China
  - Discovery and classification of new species is of particular interest, also genetics & heredity
  - USA, UK, and Argentina are major collaborators
  - Genetics research papers overlap with *Microbiology & Infectious Diseases*
  - Research on species populations and ecologies overlaps with *Plant and Animal Sciences* category
- Microbiology & Infectious Diseases -(2887 Records)
  - Largest of the 16 categories at this level of Brazil's SCI/SSCI research taxonomy
  - Heavy emphasis on microbiology, parasitology, immunology, tropical medicine and public health
  - USA, UK, France, and Germany are all frequent collaborators
  - Papers from this category which discuss genetics research tend to overlap with *Taxonomy and Evolutionary Biology*
  - Overlap with *Plant and Animal Sciences* appears to occur because abstracts for both these areas contain terms referring to 'species' and 'populations'
  - Generally,.Diagnosis and HIV/AIDS and Hepatitis research articles overlap with the *Diagnosis and Treatment of Human Patient Diseases* category
- Diagnosis and Treatment of Human Patient Diseases-(2708 Records)
  - Second largest category at this level of the taxonomy
  - Broadly covers surgery, imaging techniques, clinical and psychiatric diseases, treatment, and detection.
  - USA, Canada, UK, Italy, and Germany are countries most involved in collaborative work
  - HIV/AIDS and Hepatitis research articles overlap with the *Microbiology & Infectious Diseases.*
  - Clinical Trials overlap with *Pharmacology & Drug Research*
- Molecular & Cell Biology; Biophysics-(1678 Records)
  - Research centers on proteins, gene expression and activation, cell growth and chemical reactions at the cellular level.
  - USA, France, UK, and Germany are most frequently collaborating countries
  - Records describing drug reaction mechanisms overlap with *Pharmacology & Drug Research*
  - Studies of plants at the cellular level are cause for overlap with *Soils and Crops*
- Pharmacology & Drug Research-(1374 Records)

- Includes clinical trials, drug action mechanisms, laboratory animal research and drug development
- USA, UK, and France are the most involved in international research partnerships
- Clinical Trials overlap with *Diagnosis and Treatment of Human Patient Diseases*
- Records describing drug reaction mechanisms overlap with *Molecular & Cell Biology; Biophysics* category
- Some records which focus on endocrinology overlap with *Dairy and Livestock; Veterinary Medicine*

Figure 11 - SCI/SSCI Level 4 Cluster Map



EC Taxonomy Results

Figure 12 shows the first four levels of the hierarchical taxonomy from EC. This taxonomy was derived with 256 fuzzy clusters from CLUTO, as run on Titles and Abstracts of 21753 publications from January, 2003 through February, 2007.

The format of this diagram is the same as in the SCI/SSCI taxonomy in Figure 10. The categories and research thrusts of the EC taxonomy will be compared to those reported by Kostoff et.al (2006a.) That taxonomy diagram is included in the appendix of this report. Note that direct comparisons cannot be drawn because Brazil's results are based on a fuzzy clustering algorithm and China's clusters were allowed no overlap, but general obervations can still be made about the relative published research emphases.

The first level EC taxonomy breaks with 11839 records in *Life Sciences & Materials* and 12452 records in *Physics, Mathematics & Computer Science*. There are 2538 records common to both of these clusters, or 11.6% overlap. This is more overlap than the 9.6% observed in the SCI/SSCI taxonomy. This may be a result of differences in topical coverage of the SCI/SSCI database, which covers more life sciences and social sciences, and that of the EC, which includes more engineering journals and conference proceedings. One hypothesis is that the there is more cohesion among terminology in engineering literature than in scientific literature, generally. In future analyses, separate stopwords lists for EC and for SCI/SSCI clustering may be in order. Given EC emphases, we do not feel that the close balance for Brazil here alters our general sense that Brazil's relative strength lies in the life and biomedical sciences.

At Level 2, the *Life and Geo-sciences/Energy Sources* category emerges as foci of Brazilian research, but such a category is not found in China's Taxonomy, which places much heavier emphasis on mathematics and physical sciences. Absent from Brazil's taxonomy at this level are well-defined disciplines within engineering.

At Level 3, we observe that *Biomedical and Geo-sciences* remains a major research thrust for Brazil, and a similar category in China's taxonomy has not yet emerged. For Brazil, the largest cluster at this level is *Modeling of Physical and Mechanical Systems*, which may be similar to China's large cluster for *Physics of Structural Mechanics and Materials.*

Figure 12 - EC Taxonomy

Based on Titles and Abstracts 21753 records for papers published between Jan. 2003 and Feb. 2007

Level 1	Level 2	Level 3	Level 4
(11839) Life Sciences & Materials	(6710) Life and Geo-Sciences/Energy Sources	(4488) - Biomedical & Geo-Sciences	(2090) – Agricultural and Geo-Sciences
			(2582) - Biotechnical and Biomedical Research
		(2543) - Energy Systems & Industrial Chemicals	(2418) –Generators, Fuel Cells, and Batteries
			(306) - Industrial Chemicals
	(5927) Materials Science	(1395) – Thin Films & Microchips	(858) – Thin Films Processes and Measurements
			(769) – Microchips and Integrated Circuits
		(4845) – Molecular Composition of Materials	(1414) – Metals and Building Materials
			(3685) – Analysis of Material Microstructures
(12452) Physics, Mathematics & Computer Science	(7033) Math/Physics	(2322) – Atomic/Molecular Physics	(1651) – Quantum Physics
			(813) – Properties of Magnets and Magnetism
		(5313) – Modeling of Physical/Mechanical Systems	(3276) – Mathematical Physics, Theory and Equations
			(2673) - Fluid Physics & Thermodynamics
	(6522) Computers & Communications	(4860) – Commercial Enterprises	(2413) – Macro-Scale Power Systems
			(2724) – Computer Programming and Architecture
		(2302) –Networking and Data Processing Systems	(879) – Neural and Communications Networks
			(1545) - Data Processing, Imaging Systems & Algorithms

For the EC Taxonomy Level 4 we also provide Figure 13 to see the degree of overlap (shared records) among the respective 16 clusters within this level. As with SCI/SSCI, we next describe each cluster's content in brief and note commonalities with other Level 4 clusters. [Recall that EC does not facilitate identification of international collaboration.] Section 7 suggests interactive ways to probe the data further in pursuit of one's particular interests. Note that EC offers two powerful, complementary indexes – Class Codes and Controlled Keywords – to help locate topics of interest.

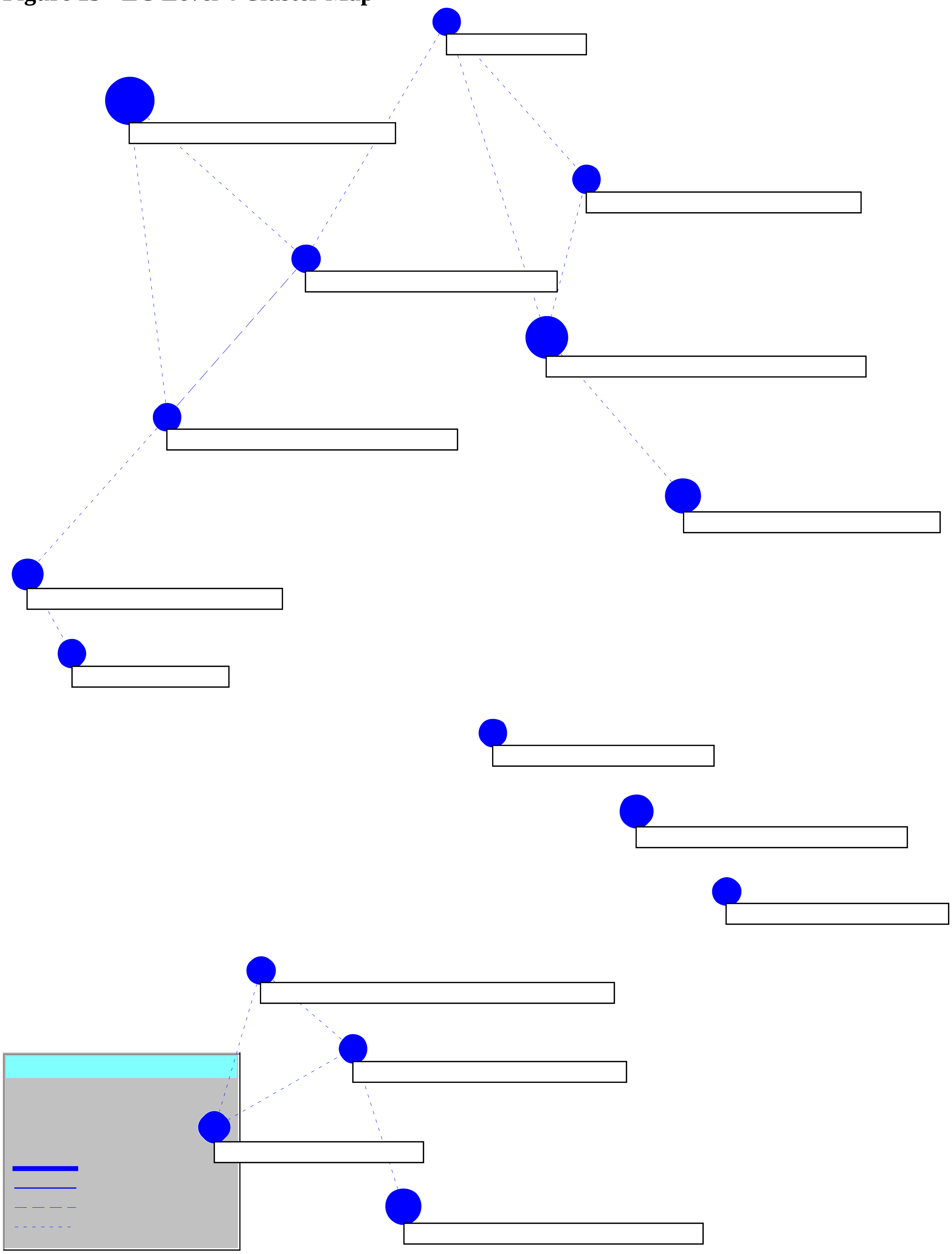
<u>Level 4 EC Clusters</u>

- Agricultural and Geo-Sciences (2090 Records)
    - Soils, pollution, water quality, and weather monitoring are the main thrusts in this category
    - No strong overlap with any categories at this level
- Biotechnical and Biomedical Research (2582 Records)
    - Emphasis on cell biology and biochemical reaction mechanisms especially those related to proteins and enzymes.
    - No strong overlap with any categories at this level
- Generators, Fuel Cells and Batteries (2418 Records)
    - Includes oxidation/reduction reactions, electrolytes, and electrochemistry, generally
    - Articles about large scale electricity generators overlap with the *Industrial Chemicals* category
    - Some of the electrochemistry research crosses over to *Thin Films Processes and Measurements*
- Industrial Chemicals (306 Records)
    - Catalysts, chemical agents, and by-products of chemical usage in industrial processes are a central theme of this category.
    - Articles about large scale power generators overlap into *Generators, Fuel Cells and Batteries*
- Thin Films Processes and Measurements (858 Records)
    - Covers layering, substrates, and measurements of thin films
    - Strong overlap with *Microchips and Integrated Circuits* because processes discussed in this category are used in chip manufacture.
    - Some of the electrochemistry research crosses over to *Generators, Fuel Cells and Batteries*
    - Measurement techniques and molecular structures are discussed in articles that overlap with *Analysis of Material Microstructures*
- Microchips and Integrated Circuits (769 Records)
    - Micro-and nano-scale electronics and ion-implantation methods are the central focus.
    - Strong overlap with *Thin Films, Processes and Measurements* because chips may be manufactured by methods described by articles in that category.
    - Diffraction analysis techniques mentioned in abstracts of these articles cause category overlap with *Analysis of Material Microstructures*

  - Publications on optical devices and absorption spectra overlap into *Quantum Physics*
- Metals and Building Materials (1414 Records)
  - Structural mechanics of metals, alloys, and materials used in macro-scale construction are the central themes of this cluster.
  - No strong overlap with any categories at this level
- Analysis of Material Microstructures (3685 Records)
  - Largest of the Level 4 cluster categories
  - Measurements and analysis of the properties of fibers, ceramics, powders, crystals, and composite materials generally describe this category
  - Measurement techniques and molecular structures are discussed in the abstracts of articles in the *Microchips and Integrated Circuits* and *Thin Films Processes and Measurements* categories
- Quantum Physics (1651 Records)
  - Quantum physics, electron energy states, spin, and density clouds, and light emission spectra are central themes to this cluster
  - Publications on optical devices and absorption spectra overlap into *Analysis of Material Microstructures*
  - Effects of magnetic fields on particles are also discussed in articles overlapping to the *Properties of Magnets and Magnetism* category
  - Publications in statistical mechanics and probability functions overlap with *Mathematical Physics, Theory and Equations*
- Properties of Magnets and Magnetism (813 Records)
  - Physics of magnetic fields and fluids are central themes of this category
  - Publications also found in the *Quantum Physics* category share a common interest in particle spin and field effects
  - Publications on probabilistic aspects and system modelling overlap with *Mathematical Physics, Theory and Equations*
- Mathematical Physics, Theory and Equations (3276 Records)
  - Modelling of statistical and fluid mechanics systems, probability and distribution functions, mathematical proofs and methods are the major thrusts of this category
  - Publications in Statistical Mechanics and probability functions overlap with *Quantum Physics*
  - Publications on probabilistic aspects and system modelling overlap with *Properties of Magnets and Magnetism*
  - Other records describe methods commonly used to describe systems in *Fluid Physics and Thermodynamics*
- Fluid Physics and Thermodynamics (2673 Records)
  - Modelling fluid flow and heat transfer systems, finite element models and differential equations are discussed here.
  - Terms which describe numerical methods are also found in records in the *Mathematical Physics, Theory, and Equations* category
- Macro-Scale Power Systems (2413 Records)
  - Control systems for high-voltage/current power supplies, filters, converters, and noise reduction are the focus of articles in this category.

  - Common usage of terms such as 'signal', 'control', and 'optimization' appears to be the reason for overlap with *Data Processing, Imaging Systems and Algorithms* and *Neural and Communications Networks* categories
- Computer Programming and Architectures (2724 Records)
  - Software design, multi-agent system architecture, programming languages, internet and information systems are the major foci in this category.
  - Internet and the worldwide web are also themes discussed in abstracts of records in the *Neural and Communications Networks* category
- Neural and Communications Networks (879 Records)
  - Includes research on modelling of neural networks and artificial neural networks
  - Also contains research on computer, cellular, and communications networks and the worldwide web.
  - Medical imaging is also discussed in *Data Processing, Imaging Systems and Algorithms*
  - 'Algorithm' and 'Signal' are also thematic terms in the *Macro-Scale Power Systems* category
  - Internet and the worldwide web are also themes discussed in abstracts of records in the *Computer Programming and Architecture* category
- Data Processing, Imaging Systems and Algorithms (1545 Records)
  - Includes research on genetic algorithms, imaging systems, medical imaging, feature extraction and neural networks
  - Medical imaging is also discussed in *Neural and Communications Networks*
  - 'Algorithm' and 'Signal' are also thematic terms in the *Macro-Scale Power Systems* category.

Figure 13 - EC Level 4 Cluster Map



Recognize that you can use the Taxonomies as you choose. If you want to probe into a particular cluster, at whatever level, here are options:

- SpaceTree allows you to pursue branching from that cluster of interest one or more levels down. The SpaceTree program allows the user to:
    - Browse the Taxonomy tree interactively by selecting more refined areas of interest
    - Search for a particular term of interest and trace its path along the tree from the highest level down to the finest level of detail available.
    - View details about the terms associated with any node in the tree and the records associated with leaf-node clusters
- You can access any of the top 4 cluster tiers (in EC or SCI/SSCI) or the 256 'leaves' (SCI/SSCI) in TechOASIS. That enables you to explore these data many ways, including:
    - Cross a Taxonomy Level of interest by, say, EC Class Codes (or SCI/SSCI Subject Categories) to ascertain emphases.
    - Focus on a cell of such a Matrix to zoom in on, say, the leading authors and leading controlled keywords
    - Profile the leading research organizations to compare their emphases for a Taxonomy category or categories of interest – e.g., selected leaves (at the finest Taxonomy level).

Section 7 describes how to use these software tools with minimal "learning curve" requirements.

7. Interactive Access to the Brazilian S&T Data

We see two main uses of country study technology intelligence: 1) general research profiling, and 2) addressing specific user inquiries. This report facilitates the former – i.e., a user gaining insights into the "big picture" of Brazilian research. We discuss general tendencies and trends, point out leading research organizations, document the nature of collaborative patterns, and so forth. To a degree, the reader can gain information about specific activities from this report – to find out "who is doing what" in a given area. The Taxonomies array technological thrusts and levels of activity. However, we believe that the user who wants to answer specific questions is best served by an interactive approach. This section describes how to do so easily.

Our target audience constitutes those with suitable rights to use these data and software tools. We leave to others to determine that proper licensing is in place. We describe what is entailed in using two software tools to probe the data – SpaceTree and TechOASIS.

For readers who know how to use these software packages, this section just offers some ideas on ways to get particular interesting outputs. For those unfamiliar with the software, we show how one can apply these tools at a very basic level to obtain valuable intelligence.

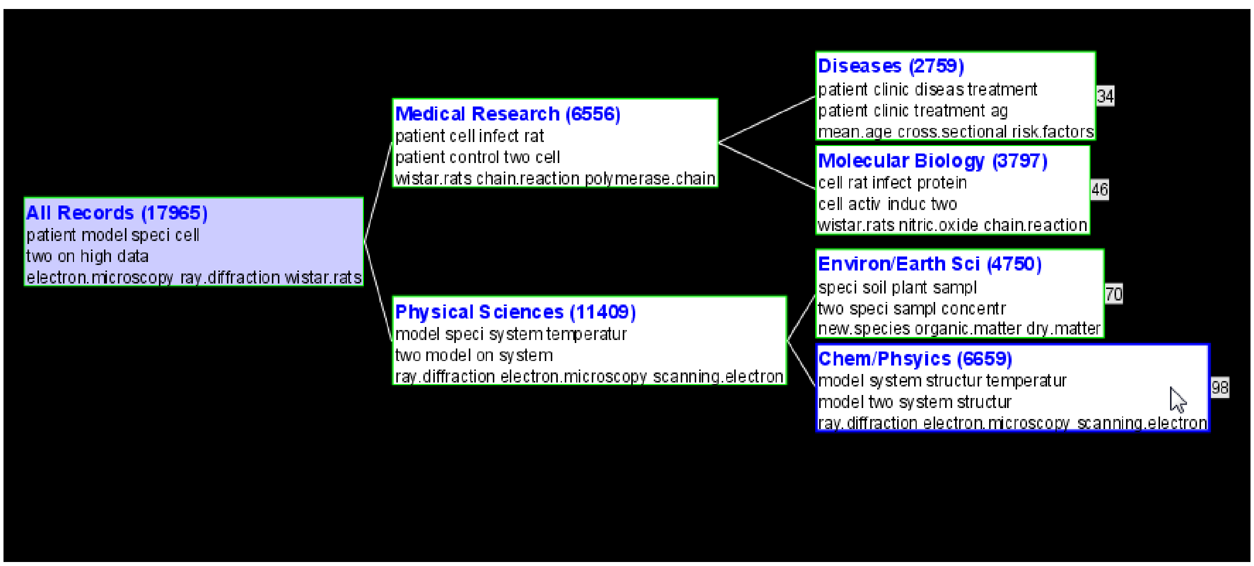
7.1 SpaceTree

SpaceTree is a node-tree browser available free for non-commercial use by the Human-Computer Interaction Lab at the University of Maryland.[24] SpaceTree is a useful tool for visualizing how the clustering results from CLUTO break out into finer detail, and the thematic terms used to describe the nodes at that detail level. Nodes can be edited or renamed to reflect the nature of these thematic terms.

Browsing a Taxonomy Tree

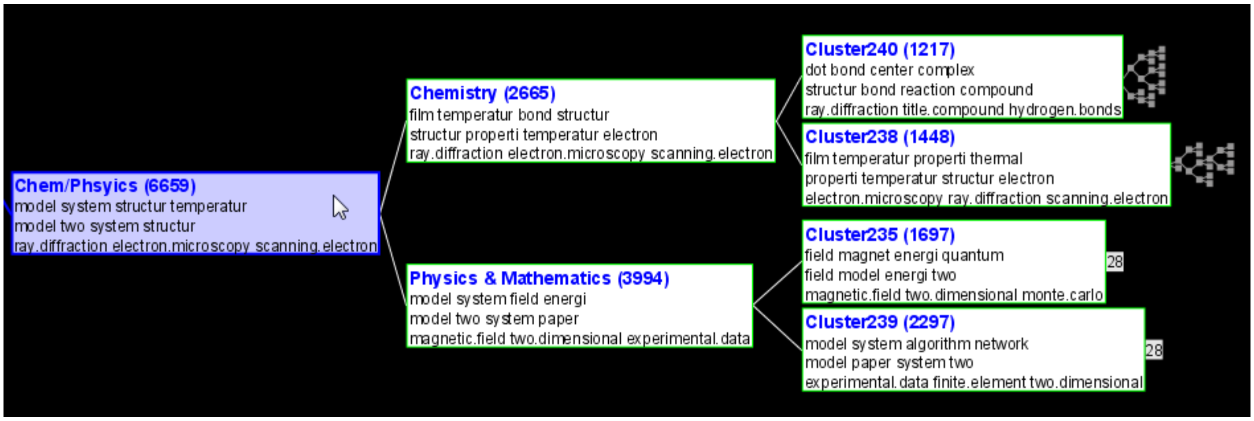
Figure 14 illustrates how one taxonomy structure might look in the SpaceTree environment. In this figure, some of the nodes have been renamed. If the Chem/Phsyics category is of interest, the user can view how literature in this category breaks out by clicking on that node with the mouse (see Figure 15). Note that the number outside the boxes of the 4 nodes at the right of the screen is the total number of branch and leaf nodes which lie beneath them. Note that these vary – Cluto does not generate a fixed number of branches at each level.

Figure 14 - SpaceTree View of Taxonomy Structure



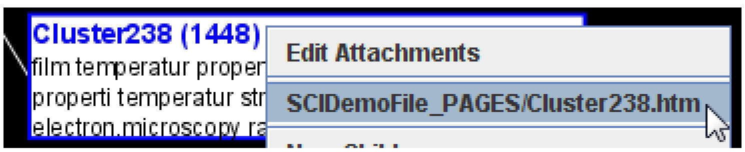
[24]The SpaceTree project website is located at http://www.cs.umd.edu/hcil/spacetree/

Figure 15 - SpaceTree View after clicking on Chem/Phsyics



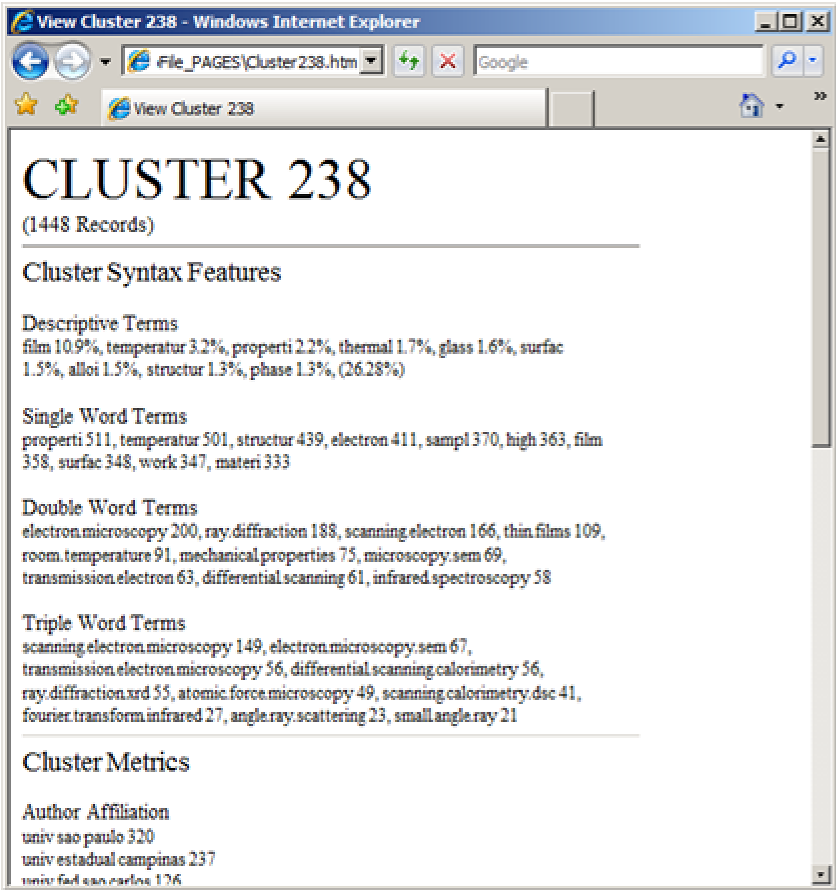
For a more detailed view of the terms in Cluster238, click on that node with the right-mouse button and select the name of the *.htm file named for that cluster (Figure 16).

Figure 16 - SpaceTree-Open *.htm file



The *.htm file for that cluster will open a web browser for viewing this content (Figure 17).

Figure 17 - Cluster Details as viewed in a Web Browser



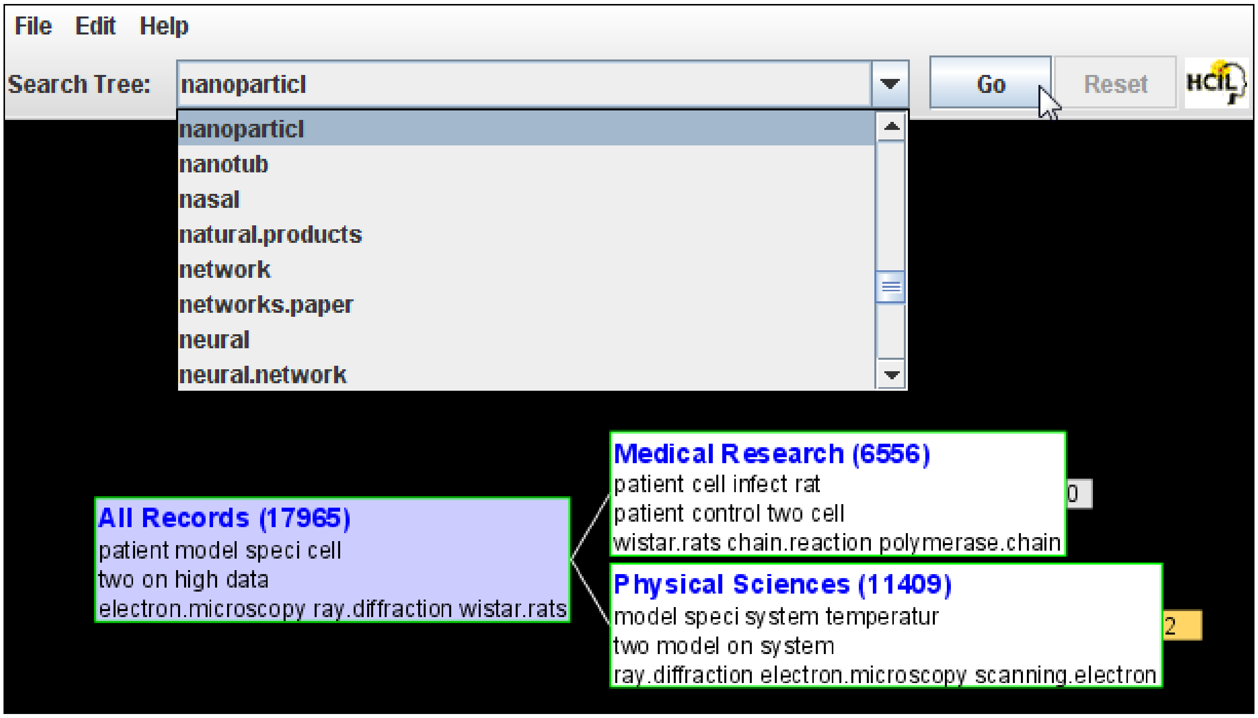
The *.htm files present information regarding the "descriptive terms" that generally describe the records in the cluster; the associated one, two, and three word phrases from these records; and metrics such as leading institutions, countries, authors, keywords, journals, etc., for records in the cluster.

<u>Searching</u>

The SpaceTree interface also allows the user to search for terms that occur in the tree. This is useful to quickly locate terms of interest and place them into context with respect to other nodes and branches of the tree.

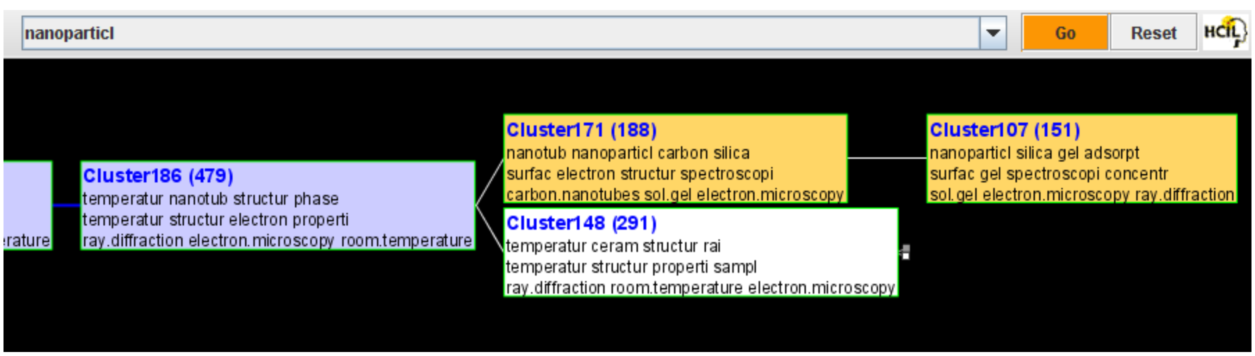
The user can search for terms by typing in the 'Search Tree' box near the top of the application window. As the user types, terms in the tree are sorted in an indexed dropdown menu. When the desired term is selected, click 'GO' (Figure 18).

Figure 18 - SpaceTree - Entering a Search



The tree will adjust to show matching nodes, and those nodes will be highlighted (Figure 19.

Figure 19 - SpaceTree Nodes containing Search Terms



SpaceTree provides a fine orientation to place research activity in context. It nicely sets one up to analyze that research activity further in TechOASIS.

7.2 TechOASIS

This text mining software is available for any Federal Government users. Some readers may have access to commercial versions of the software – *VantagePoint* or *Thomson Data Analyzer* –

those will work with the Brazil datasets as well. This is *MS Windows* desktop, analytical software with many features [see www.theVantagePoint.com]. We're focusing on just what is needed to answer selected essential questions. Those may spawn further interests; to assist which, we recommend electronic help within the software:

- searchable, indexed "Help" files
- "Analyst Guide" – flash and text expositions, including a) Introductory demonstrations, b) an Analyst's Handbook with pointers on how to do clustering, "4W analyses" (answering who, where, what, and when questions); and c) Walkthroughs to get particular types of results.

If you need additional assistance, go to: http://www.thevantagepoint.com/contact.cfm

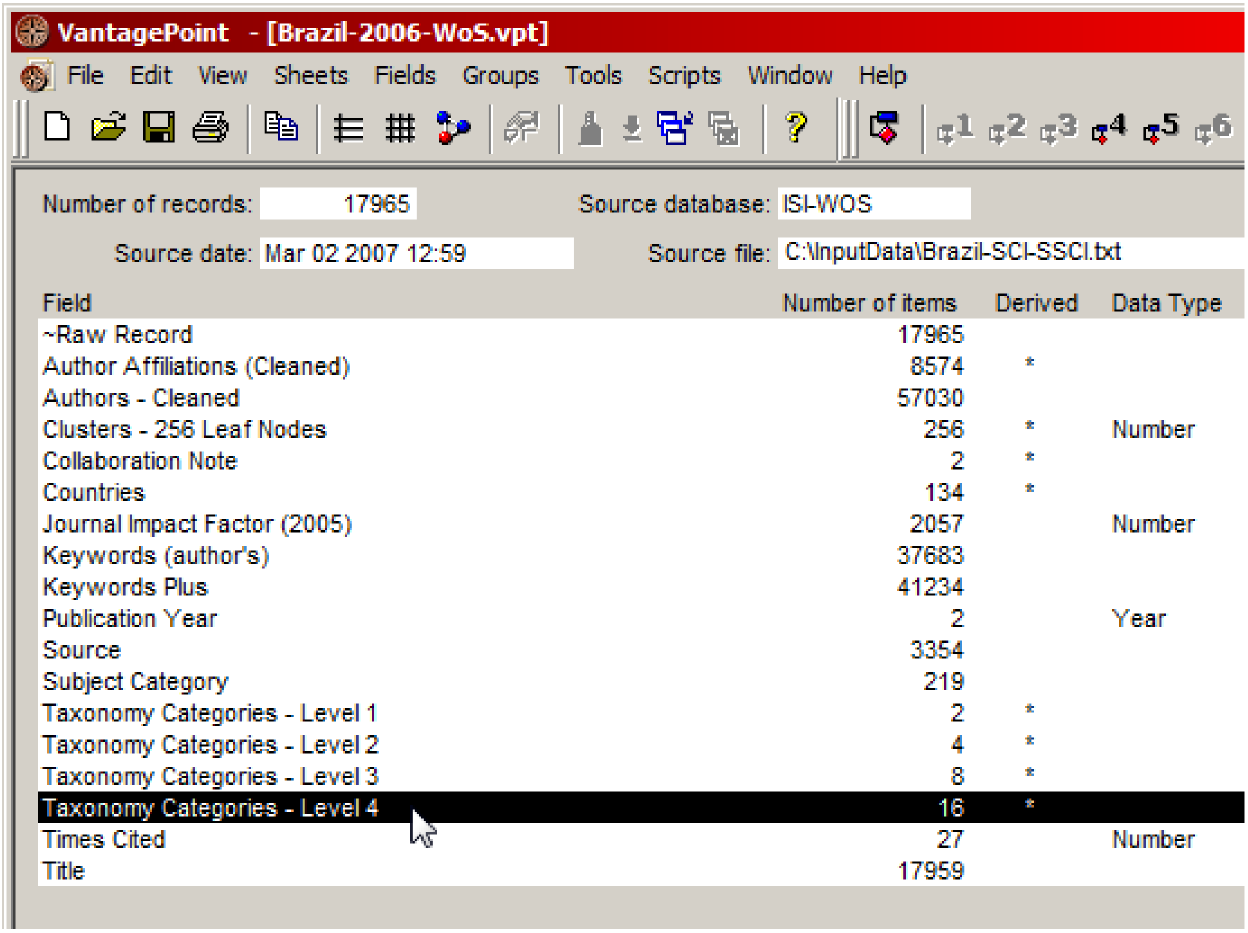
We organize this section in three parts: A) Basic Operations, B) "Scenarios" – illustrating how to address selected questions, and C) Nuts and Bolts – commands to accomplish A and B.

A. Basic Operations

TechOASIS (the screen shots to follow show the equivalent *VantagePoint* form) files allow one to open a series of sheets (somewhat like MS Excel files with separate worksheets). The "Summary" sheet tells what is in a data file. For the Brazil country study we focus on the two most up-to-date SCI/SSCI (2006) and EC (2003-07) data files. If one has special interests concerning other of the data files analyzed, contact us.

The illustrations that follow use the SCI/SSCI Brazil 2006 data; the EC 2003-07 data are generally comparable in form. Figure 20 illustrates the **Summary sheet** for the SCI/SSCI 2006 data file. This shows the available fields and tells some information about them. Note that Taxonomy information is available – the top 4 levels and the clusters at the level of the "256 leaf nodes."

Figure 20 - TechOASIS Summary Sheet


VantagePoint - [Brazil-2006-WoS.vpt]

File Edit View Sheets Fields Groups Tools Scripts Window Help

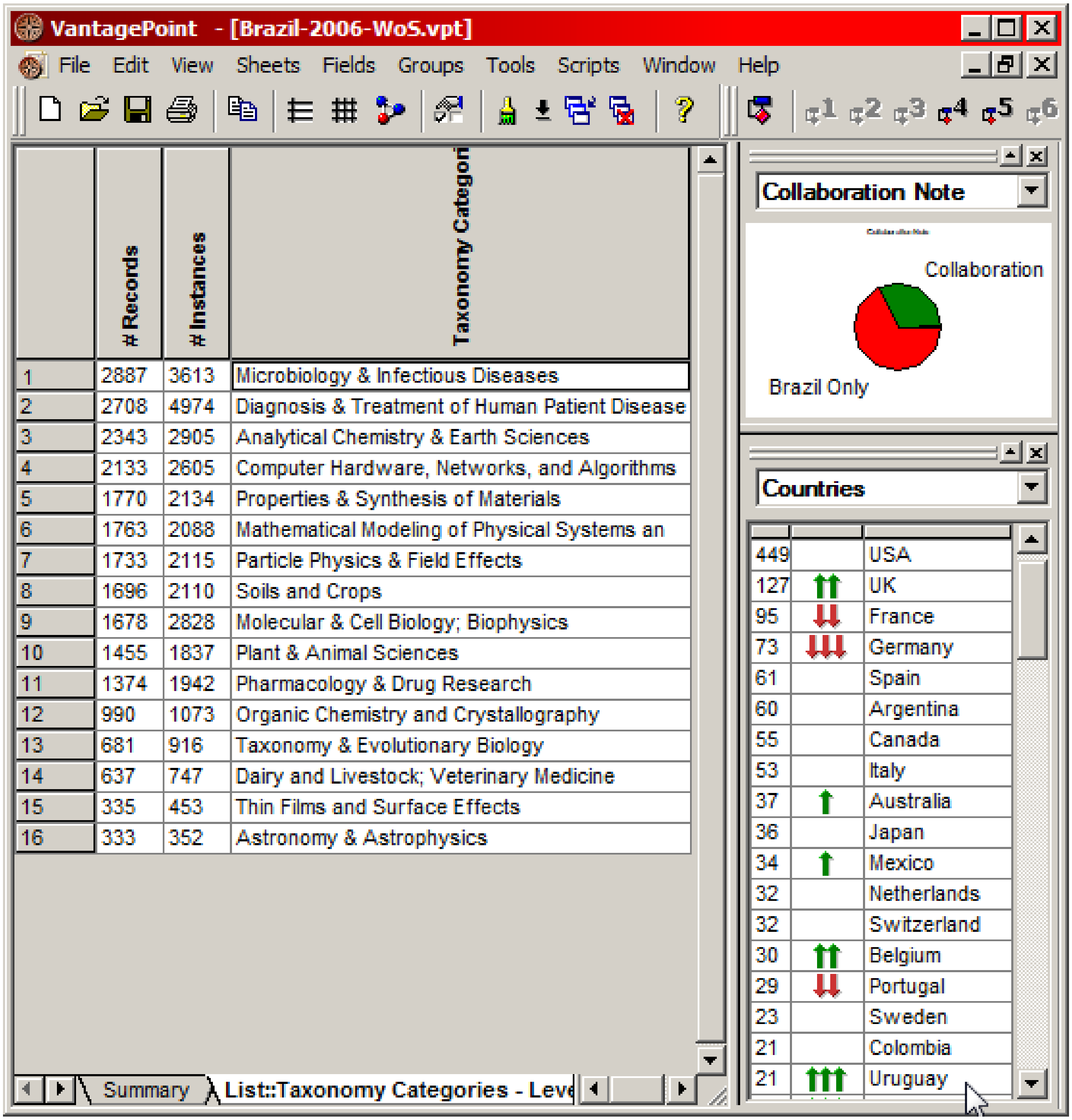
Number of records: 17965 Source database: ISI-WOS

Source date: Mar 02 2007 12:59 Source file: C:\InputData\Brazil-SCI-SSCI.txt

Field	Number of items	Derived	Data Type
~Raw Record	17965		
Author Affiliations (Cleaned)	8574	*	
Authors - Cleaned	57030		
Clusters - 256 Leaf Nodes	256	*	Number
Collaboration Note	2	*	
Countries	134	*	
Journal Impact Factor (2005)	2057		Number
Keywords (author's)	37683		
Keywords Plus	41234		
Publication Year	2		Year
Source	3354		
Subject Category	219		
Taxonomy Categories - Level 1	2	*	
Taxonomy Categories - Level 2	4	*	
Taxonomy Categories - Level 3	8	*	
Taxonomy Categories - Level 4	16	*	
Times Cited	27		Number
Title	17959		

The most basic TechOASIS capability is to **LIST** the contents of a field. For instance, Figure 21 lists the 16 Level 4 categories. One can readily see lists for any of the other fields. The "Records" are the 17965 article abstract documents gathered from SCI/SSCI (Web of Science – WOS). Cluto clustered 2887 of those together in a category that we named "Microbiology & Infectious Diseases." As per Section 6, Cluto fuzzy clustering locates some abstract records into multiple categories. We clustered down to the "leaf" level of 256 categories. So, if a given record was assigned to several of those that branch from "Microbiology & Infectious Diseases," the "Instances" count at Level 4 will be higher. Put another way, the Instances tally of 3613 tells us that a good number of the 2887 records reflect such multiple leaf assignments that fall within this category.

Figure 21 - Sample List: The Level 4 Taxonomy Categories

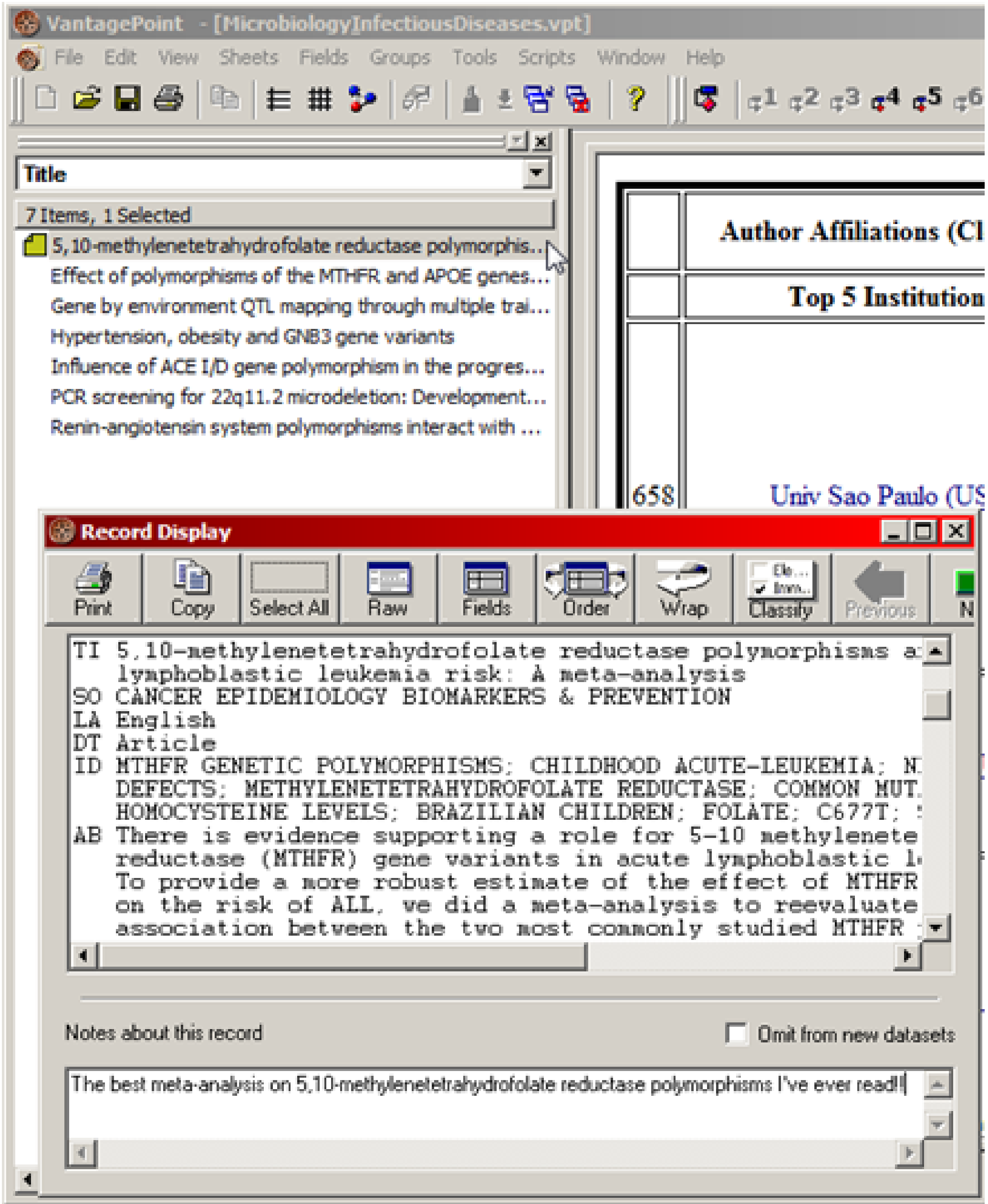


To the right of the Taxonomy list, we have opened two "Detail Windows." The top one shows some derived information on the extent of international collaboration for the selected List item ("Microbiology & Infectious Diseases"). The bottom Detail Window lists the Countries with authors on these papers that all have Brazilian authors too. Were we to click on another Taxonomy category, these windows would update for it.

One can display any of the available fields for entities in a List (or cells in a Matrix or nodes in a Map) in Detail Windows. In this way one can instantly break out a given entity's other characteristics. For instance, we could open a "Countries" List, click on "Iran," and open a Detail Window to check which "Subject Categories" and which "Author Affiliations" are involved in the 7 articles co-authored with Brazilians.

Figure 22 illustrates another way to "zoom in" to investigate particulars. For a chosen entity in the main display area (in this case, a "Profile" to be described in Figure 25), we have shown 7 article Titles in the window on the left side of the sheet. By double-clicking on one of those, we open a "**Record Display**." One can thereby read individual abstract records for areas of particular interest. [You can make notes or classify records into user-defined fields here if desired.]

Figure 22 - Sample Record View

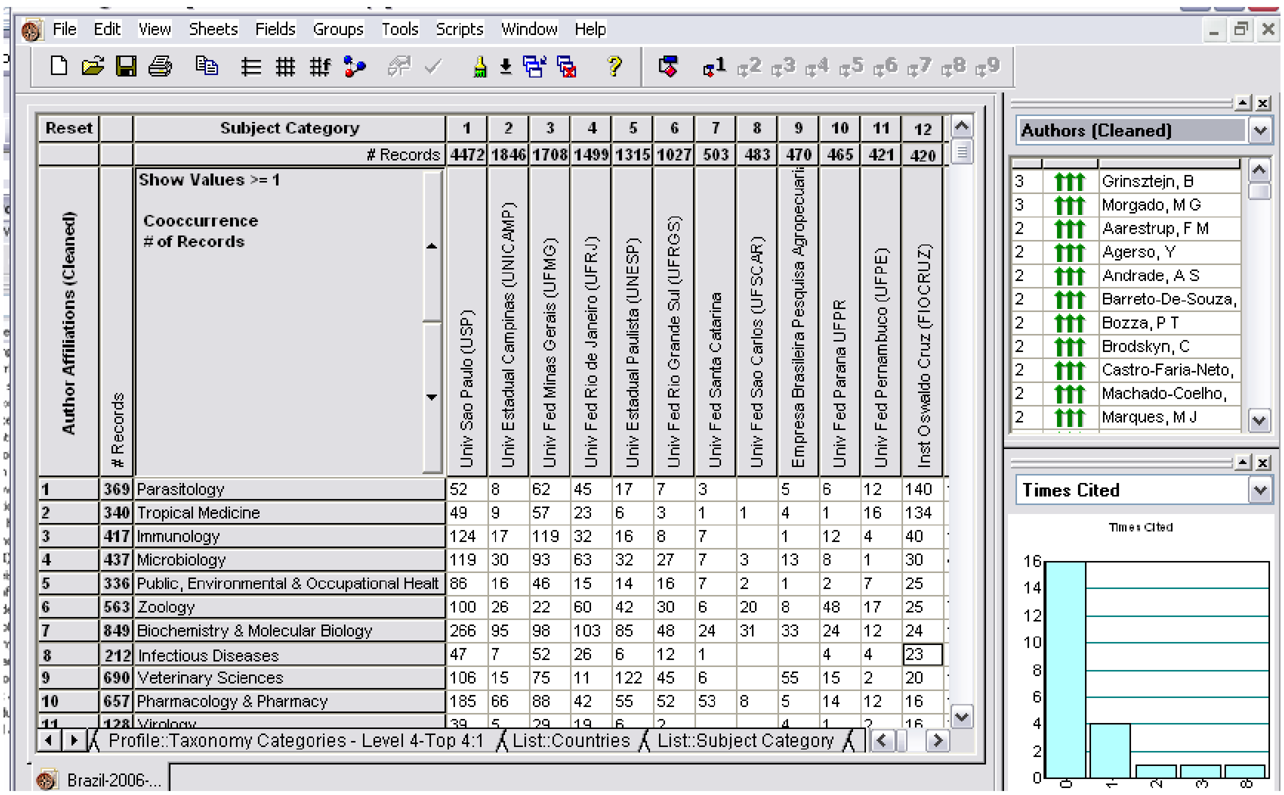


Some Lists that we use heavily are:

- Research organizations (author affiliations)
- Authors
- Publication years
- Countries
- Subject Categories (SCI/SSCI)
- Class Codes (EC)
- Keywords (controlled) (EC)

Figure 23 shows a **MATRIX** – this combines any two Lists. Here we array the SCI/SSCI Subject Categories against the Research Organizations (Author Affiliations). The Matrix can include all the items in the two lists, or a subset of a selected Group (e.g., the "top 10").

Figure 23 - Sample Matrix: Subject Categories by Research Organization



In this illustration, we have selected a cell at the intersection of FIOCRUZ and Infectious Diseases. The Detail Windows that are open tell us about those 23 articles – their authors and the distribution of citations to the articles (only three have received more than 1 citation).

Some illustrative matrices that may be handy (but any combination of Lists may suit your particular needs):

- Taxonomy Level 4 Clusters by Research Organization
- Taxonomy Level 4 Clusters by Country (SCI/SSCI)
- Keywords (controlled) by Publication Year
- Author by Author [Note that this would be a huge matrix; probably handier to first make a group of "Top" Authors in the List, then in the Matrix Wizard Window, specify that group]

Figure 24 demonstrates another TechOASIS capability to help ascertain relationship through a **MAP**. Here we show selected top research organizations based on the similarity of the Subject Categories in which they publish. Highlighted is Univ. Fed. Vicosa (UFV). In Section 5 we had

speculated that UFV likely emphasized agricultural research (based on commonalities with EMBRAPA). Here, the Detail Windows suggest that this is the case. Again, one can choose any fields to show in the Detail Windows – e.g., authors, taxonomies.

Figure 24 - Sample Cross-Correlation Map of Leading Research Organizations based on Subject Categories

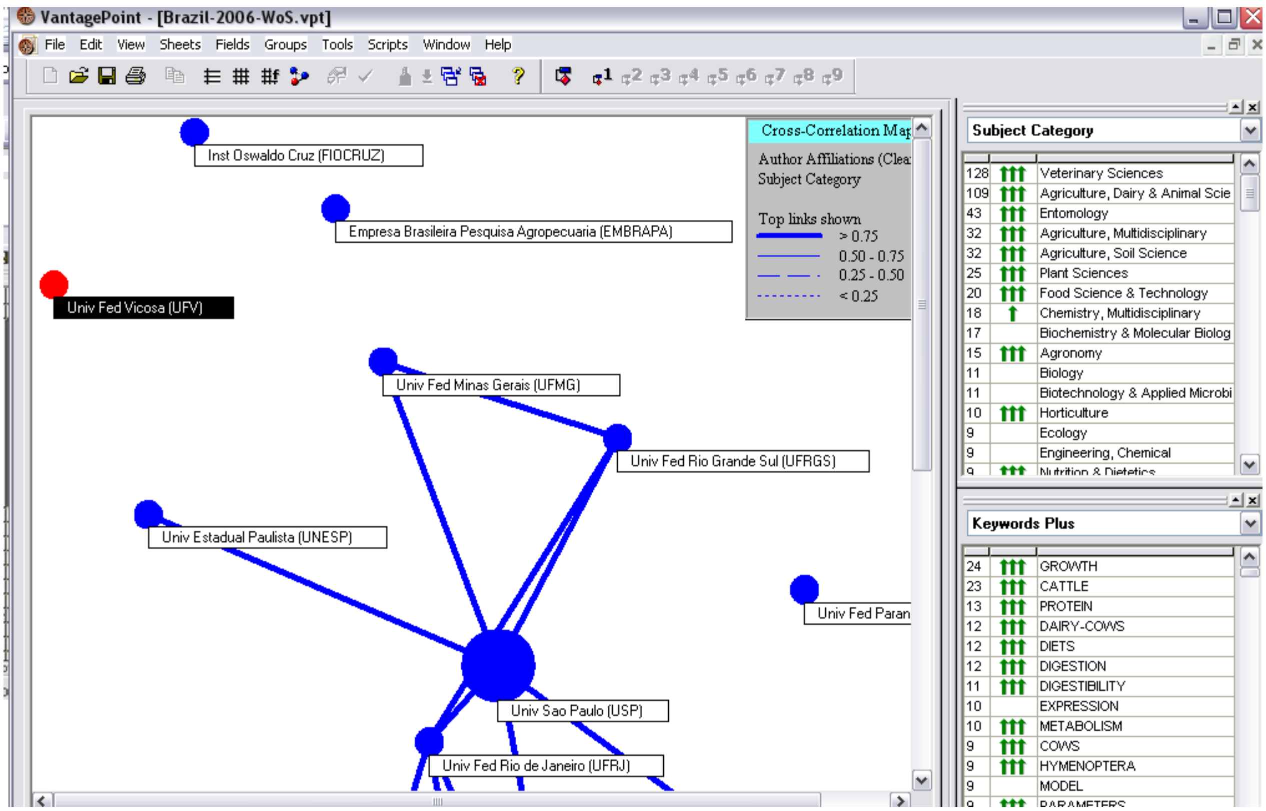
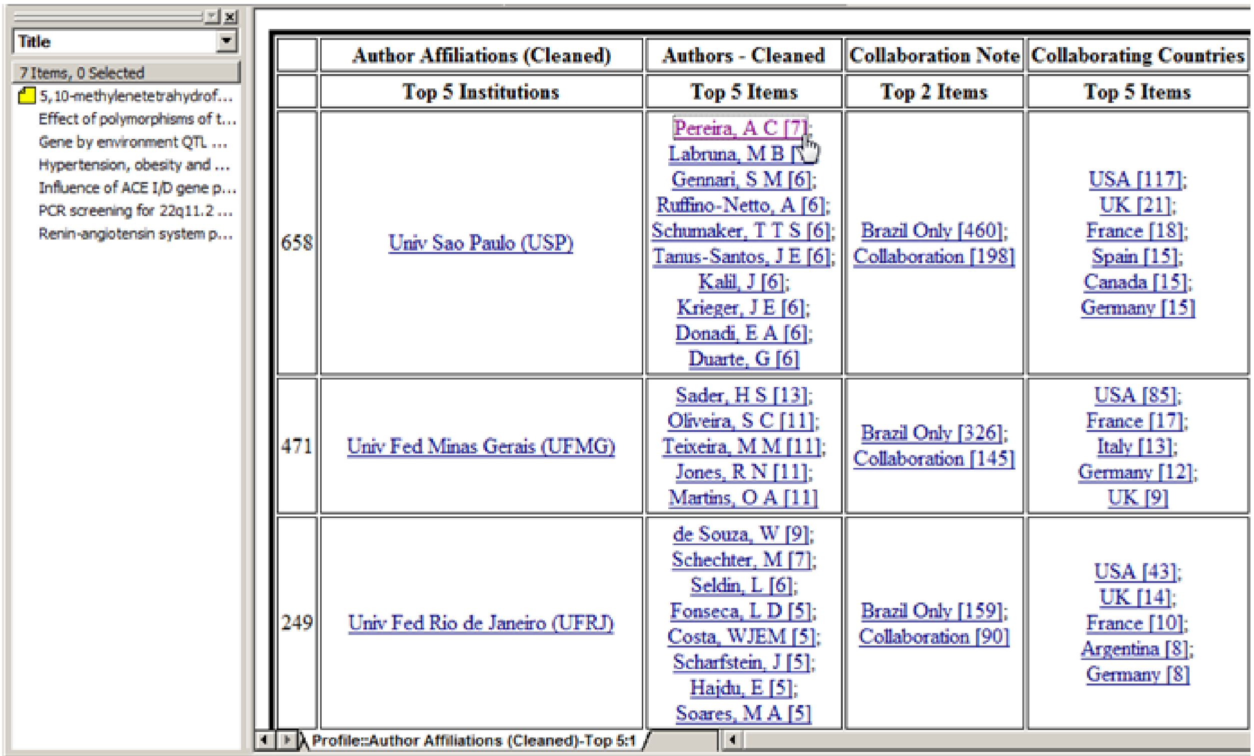


Figure 25 presents the last basic tool that we introduce – **RESEARCH PROFILING**. Here we illustrate for three leading research organizations associated with the Taxonomy Level 4 category -- "Microbiology & Infectious Diseases." We have chosen to break out the top authors, degree of international collaboration, and top collaborating countries – just for articles assigned to this category. Were we so inclined, we could probe further – e.g., to use Detail Windows to spotlight leading authors in the USP-USA collaborations. Upon so doing, we can quickly point to HS Sader and RN Jones at JMI Labs in Liberty, Iowa, possibly to contact these researchers to learn more about their Brazilian collaborations.

Figure 25 - Sample Research Profile for Leading Organizations



	Author Affiliations (Cleaned)	Authors - Cleaned	Collaboration Note	Collaborating Countries
	Top 5 Institutions	Top 5 Items	Top 2 Items	Top 5 Items
658	Univ Sao Paulo (USP)	Pereira, A C [7]; Labruna, M B [7]; Gennari, S M [6]; Ruffino-Netto, A [6]; Schumaker, T T S [6]; Tanus-Santos, J E [6]; Kalil, J [6]; Krieger, J E [6]; Donadi, E A [6]; Duarte, G [6]	Brazil Only [460]; Collaboration [198]	USA [117]; UK [21]; France [18]; Spain [15]; Canada [15]; Germany [15]
471	Univ Fed Minas Gerais (UFMG)	Sader, H S [13]; Oliveira, S C [11]; Teixeira, M M [11]; Jones, R N [11]; Martins, O A [11]	Brazil Only [326]; Collaboration [145]	USA [85]; France [17]; Italy [13]; Germany [12]; UK [9]
249	Univ Fed Rio de Janeiro (UFRJ)	de Souza, W [9]; Schechter, M [7]; Seldin, L [6]; Fonseca, L D [5]; Costa, WJEM [5]; Scharfstein, J [5]; Hajdu, E [5]; Soares, M A [5]	Brazil Only [159]; Collaboration [90]	USA [43]; UK [14]; France [10]; Argentina [8]; Germany [8]

B. Three Research Intelligence Scenarios

To trigger your thinking of ways to use these data, we offer brief "imagine this" situations.

1) You're going to a Conference on Corrosion, in Sao Paulo. You'd like to know a bit about the research interests of some leading Brazilian researchers. You're thinking of using that information to make pre-conference contact to see who's attending and alert them to your interests, perhaps even ask them to 'snowball' you toward others whose interests closely match your own.

So, you open the EC.vpt file and list the Cluster Themes @Taxonomy Level 4. You select the "Corrosion & Durability Tests" category. You could now just open a Detail Window to see some leading authors. You might then select the top handful and even create a new sub-dataset to examine their papers in more detail. From a List of Authors we quickly locate Amauri Garcia in the Department of Materials Engineering at UNICAMP….

2) You've been asked to identify some researchers addressing yellow fever. You use "Find" on the SCI/SSCI titles to select the 9 with "yellow fever" in the title. You open a Detail Window for "Author Affiliations" (noting that six of the articles have FIOCruz authors). You open a second Detail Window for "Authors" to get their names. You pop open "Record Display" to

read those six abstracts to see if these seem well-targeted. If so, you make a quick Auto-correlation Map to see their co-authoring network to identify the central researcher.

3) You're helping to organize a conference. You're hunting for a few eminent Brazilian researchers who are currently actively researching ethanol. In the SCI/SSCI file, open a List for "~Raw Record" to "Find" ethanol anywhere in the record. You find 387; that's a lot, so make a sub-dataset of just them. In this new ".vpt" file, open an Authors List. Open a couple of Detail Windows, say, for "Author Affiliation" and for "Subject Category." Select the most prolific authors one at a time to see where they are located and their research emphases. For promising candidates, open a Detail Window on "Times Cited" to get a quick read on how highly regarded each one's work is.

Tag the ethanol researchers you find particularly promising in a new Group. Now generate a Research Profile for these researchers to compare at a glance the Subject Categories and Taxonomy categories in which their work appears, organizational affiliations (to assure diversity), times cited and journal impact factors (indicators of quality), and possibly other fields that you want to check. For your prime prospects, use their author affiliation information to aid in getting e-mail addresses to invite them.

Here are a few more ideas on TechOASIS outputs that could help address particular questions about Brazil's research capabilities:

- EC data file: Look at a matrix of 1) Class Codes or Keywords (controlled) by 2) Research Organization – to gain additional perspective on research thrusts (who is doing what).
- For the data subset of US-co-authored papers, make a matrix of Research Organization by Research Organization – to see who is collaborating with whom [for either EC or SCI/SSCI data files].
- Table 24 breaks out international collaboration by Taxonomy Level 4 Clusters. If you wanted to explore USA collaboration on one of these, you could make a Matrix of Countries by Taxonomy Categories – Level 4; select the cell of special interest; and create a Sub-dataset file of just those records to explore.
- For a chosen data subset (e.g., a particular Taxonomy category or a Group of articles using particular keywords), generate an auto-correlation map to see who is collaborating with whom in this research area.
- "Dig down" – TechOASIS offers various ways to explore in depth. For example, recall the International Collaboration Profile (Table 24). One might pick one Taxonomy category, for one country, and make a new sub-dataset for that body of research. Then for that new ".vpt" file, explore topical emphases of the key research organizations and interactions with US research organizations.

C. TechOASIS "Cheat Sheet"

Here is a handy list of what you need to do to get the results illustrated in Sections A and B. For many of these operations, there are alternative ways to do them. For many objectives, there are several approaches that will work. We try to keep this short by just showing how to get a small sample of results – one way. We point to the aforementioned *VantagePoint* electronic Help and Analyst's Guide for in-depth support.

Table 31 - TechOASIS "Cheat Sheet"

Task	**Action to do it**
Help	Pull-down Menu - Help
Open a VantagePoint file (.vpt)	Pull-down Menu - File - Open
Find out about or manipulate a Field	In Summary sheet - right-click on that Field
Make a List of the contents of a Field	In Summary sheet - double-click on that Field
List: Sort it	In that List sheet - double-click in the header above that Column (toggles; do it again to reverse)
List: Search it	In that List sheet - Pull-down Menu - Edit - Find
List: Make a Group	In that List sheet - Pull-down Menu - Groups - Edit Groups
List: Add items to a Group	Manually add check at that item in the Group, or Select a number of items; go into Pull-down Menu- Groups - Edit Groups - Select the Group desired - "Add"
Make a Matrix	Pull-down Menu - Sheets - Add Matrix (window opens to guide you)
Add Detail Window	In that sheet - Pull-down Menu - View - Add Details Window
Detail Window: Change contents	Pull down the list of Fields within the Detail Window and select
Detail Window: Change display	Within the Detail Window, right-click and select desired form
Open Title Window	In that sheet - Pull-down Menu - View - Add Title Window
Read abstract records	Double-click the Title (in Title View) of the record to read; "Record Display" opens
Make Cross-correlation Map	Pull-down Menu - Sheets - Add Map - check Cross-correlation; follow Wizard guidance to select fields; if the Fields have many items, you should first go to the respective List and create a Group of just those items whose interactions you want to map (e.g., author affiliations based on shared usage of keywords)
Make Auto-correlation Map	Pull-down Menu - Sheets - Add Map - check Auto-correlation; follow Wizard guidance to select the field to map; if the Field has many items, you should first go to its List and create a Group of just those items whose interactions you want to map (e.g., co-authoring)
Research Profiling	Pull-down Menu - Scripts - Select the one you want (e.g., SuperProfile - follow instructions
Create new sub-dataset	Pull-down Menu - File - Create Sub-dataset - Check either Group or Selection and indicate from which Field
List Clean-up (e.g., to help consolidate author name variations in EC)	Pull-down Menu - Fields - List Cleanup - Select the Field to clean; Select the appropriate Fuzzy file to use.
Thesaurus (e.g., to combine name variations)	Pull-down Menu - Fields - Thesaurus - select Field on which to operate; select Thesaurus file to use. [Note; see Help on many ways to build up and apply thesauri with grouping, etc.]

This introduction should convey that you can extend these analytical breakouts many ways. You'll quickly figure out some of those. If you have a question about Brazilian research that you think should be answerable, but don't see quite how to do so, contact us [http://thevantagepoint.com/contact.cfm].

8. Explorations: Defense-oriented R&D

We approached the Brazil country study as a two-part process. The first was to prepare a report that covered the core content of an ONR country study as that has emerged as of the recent China and India studies. The second was to apply available study resources to explore ways to enhance the country study further.

Our main extensions to the country model are 1) to prepare the data for interactive access and 2) to investigate ways to extract military-relevant R&D information. The former has been presented in the previous Section. We devote the remainder of this Section to the latter. The Discussion Section notes several additional enhancements of various sorts that warrant consideration in future country studies.

Preliminary review of this study led to an ONR request to profile Brazil's defense-related research. Our review of Brazilian S&T statistics indicated that less than 2% of its R&D is funded by Defense. That moderated our expectations for what we would find in the open literature (SCI/SSCI and EC compilations) and alerted us to search generally for related interests, rather than for specific military terms. A focused study on military-related research in India looked both at military-related terms and the specific technologies associated with these terms (Kostoff and Bhattacharya in press).

We explored direct and indirect organizational approaches. We sought papers authored by researchers with military organizational affiliations. We then examined work by their non-military organizational collaborators. Likewise, we investigated direct and indirect topical approaches. That is, we compiled lists of militarily relevant themes and sought papers that addressed those. Then we reached out further for papers that related to those themes "second-hand." We see considerable promise in developing algorithmic approaches to perform such examinations for countries of interest.

This section presents the results of one possible approach toward identifying defense-related S&T research in Brazil's published literature. The content of this section is exploratory in nature, and is included for the sake of generating ideas and discussion how best to identify militarily relevant literature, rather than to paint a definitive portrait of defense-related R&D in Brazil.

Just to mention briefly, we explored other strategies also. We examined "The Militarily Critical Technologies List (MCTL)".[25] This is certainly a rich collection of pertinent topical areas. We found the Naval S&T Focus areas provided us with terms that were a better fit with the scope of this project. One issue in hunting for military-relevant topics in the open literature is to adapt terminology to fit. For instance, to pick two successive terms from the MCTL, "directional warhead for air targets" would not be expected to appear directly in EC. So, one has to use subjective judgment to imagine what R&D topics would bear on the underlying military

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[25] "The Militarily Critical Technologies List (MCTL)," *Security Awareness Bulletin*, Number 2-95. Richmond, VA: Department of Defense Security Institute [at www.dtic.mil/mctl].

interests. In contrast, the next term, "direct methanol fuel cell" could well appear (and points directly to a more general concept, fuel cell).

With Dr. Kostoff's guidance, we determined that ONR interests need not be limited to marine aspects, given air and ground interests (e.g., Marines) too. Nonetheless, certain marine topics are of special interest – one reason to favor the Naval S&T Strategic Plan target areas to guide searching.

Our first major analytical foray concentrated on EC Class Codes. We looked for direct correspondence – any Class Codes with express military interests? There are few – e.g., "military engineering." We examined the Class Codes on their own for pertinent topics, as per our judgment. We also tried to cross-locate generally interesting Class Codes against the S&T Focus Areas. After a lot of work, but not much in the way of results that we could stand behind, we shifted to the approach described here.

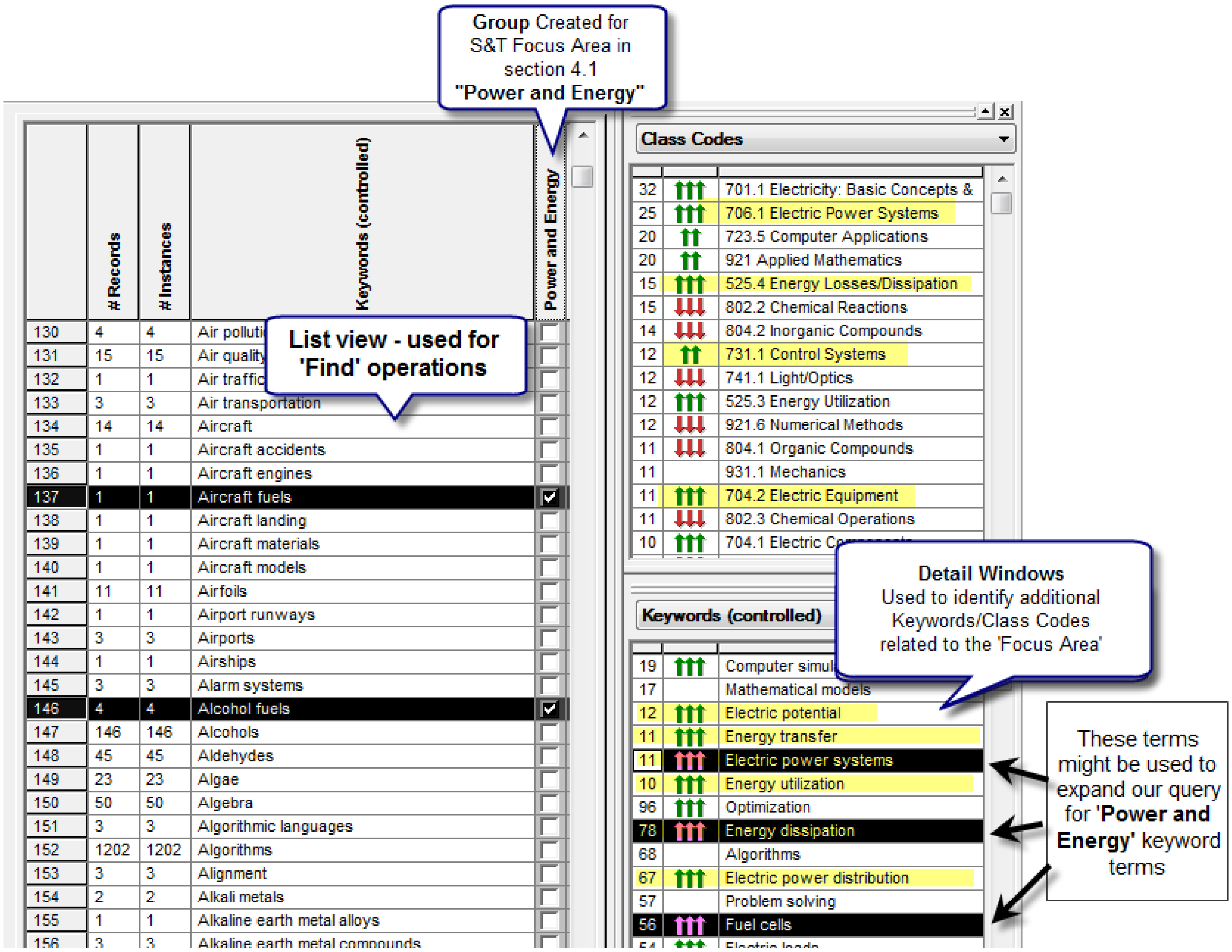
The 'Naval S&T Strategic Plan' (ONR, 2007) document was used as the basis for this understanding of defense-related R&D. We read through and manually pulled terms from the 13 S&T Focus areas outlined in Section 4 of that document (Included in Appendix).

We then used our TechOASIS data file with the 21,753 records extracted from the EC for years 2003-2007 (partial 2007) and performed a series of 'find' operations for terms we pulled for each of the 13 S&T focus areas. We grouped these terms according to which focus area(s) they intersect.

In order to broaden our search, and account for some of the human interpretation error inherent in this approach, we used Detail Windows to scan for co-occurring Class Codes or Controlled Vocabulary terms as we performed each 'Find' operation.

Figure 26 illustrates to help guide others who might try to adapt our approach.

Figure 26 – TechOASIS List and Detail Views to Help Find Relevant Research



Once we had a robust sample of records for each of the 13 categories, we created a new field in the TechOASIS dataset called **"Keywords (Defense S&T Focus Areas)"**. Of the 21753 records in the extracted EC data file, 6011 Records (~28%) include at least one controlled vocabulary term determined to have some relevance to one or more of the Defense S&T focus areas.

The number of records related to each of these categories is presented in Table 32. The specific EC Controlled Vocabulary terms grouped to each focus area are included in the Appendix.

Table 32 - S&T Focus Areas and # of Related Brazil EC Records

Section	Defense S&T Focus Areas	# Records
4.1	Power and Energy	1205
4.2	Operational Environments	707
4.3	Maritime Domain Awareness	816
4.4	Asymetric and Irregular Warfare	800
4.5	Information, Analysis, and Communication	605

4.6	Force Projection	135
4.7	Assure Access and Hold At Risk	261
4.8	Distributed Operations	467
4.9	Naval Warfighter Performance and Protection	209
4.10	Survivability and Self-Defense	272
4.11	Platform Mobility	423
4.12	Fleet and Force Sustainment	616
4.13	Affordability, Maintainability, and Reliability	1618

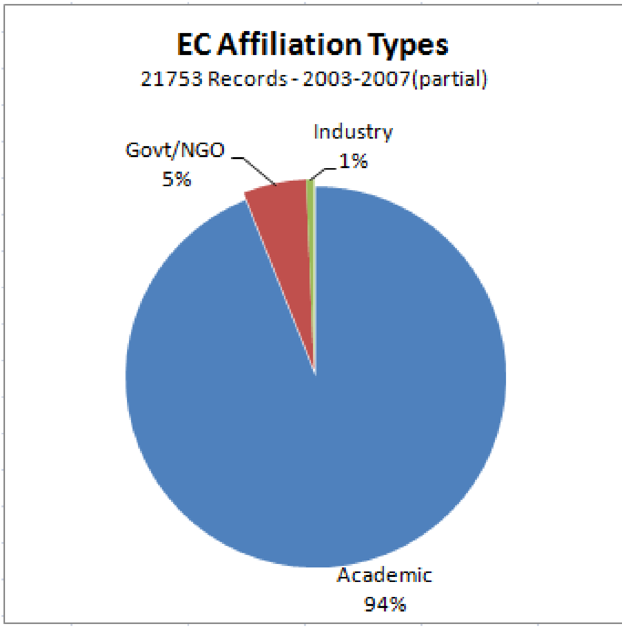
Of course, record counts for each of these focus areas are prone to the subject coverage of EC and the likelihood of research being published in that domain. The items in Table 32 with the largest number of records, "Power and Energy" and "Affordability, Maintainability, and Reliability" (with 1205 and 1618 records, respectively) are research areas that are extensively covered by the EC database. Furthermore, applications of these technologies are much less likely to be matters of national security than are items in the 'Force Projection' grouping (135 records identified), and, hence, apt to be located in the open literature.

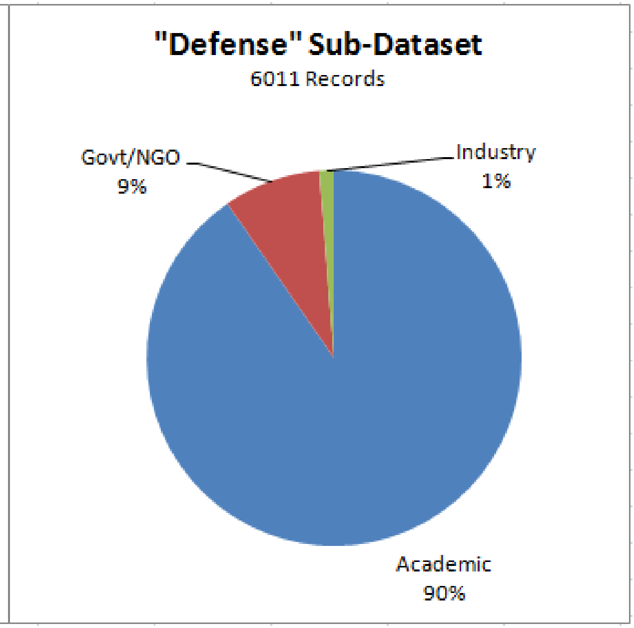
These numbers need to be cautiously interpreted as they are a representation of the authors' interpretation of the focus areas, as outlined in 'Naval S&T Strategic Plan' document and their (the authors') interpretation of which controlled vocabulary terms are relevant to a focus area. The worthiness of any one keyword term to be grouped with one focus area or another could be argued ad infinitum, and we will not engage in such discussions here (though some ideas on alternative approaches to identifying defense related R&D will be presented later in this section.)

Following the assumption that we have 6,011 defense-relevant records, we can begin to discuss some analytic capabilities that may be of interest.

From the full dataset of 21,753 EC Records, we created a sub-dataset of the 6,011 defense-related records. The "Affiliation Type" field, which classifies an author's institution as Academic, Industry, or Government/NGO, is also included in our sub-dataset so we can quickly compare the level of publication activity from each type of affiliation. We would expect to see a larger portion of the defense-related R&D coming from Govt/NGO affiliations, and a glance at Figure 27 confirms this. This also indicates forcefully that the research being identified is largely NOT conducted within such institutions (e.g., government labs), but rather, in universities. This leaves an open question as to how militarily relevant, how many of the records tallied in Table 1 might be.

Figure 27 - EC Affiliation Types: All EC v. Defense Subset





We can now take a closer look at the institutions in the Government/NGO sector and their publication activity within the Defense subset. We used TechOASIS to generate a profile snapshot of the government and NGO institutions which have published more than 10 defense-related papers in the sampled time period from 2003 to 2007 (partial).

Table 33 provides a profile of the most prolific Government and NGO institutions from the subset of 6011 defense papers. The subsequent columns indicate for each institution shown:

- Publication Activity – a measure of how much of an institution's total research since 2003 was published in 2005 or later.
- Naval S&T Focus Areas – Top 5 of the 13, as determined by controlled vocabulary terms from the institutions' publications.
- Unique Research – Keywords associated with the institution that are not indicated for any of the other profiled institutions.

As is discussed in Section 7.2 these profiles can be tailored to your particular interests. If you require sharper reports for 13 focus areas individually, instead of the 'bird's eye view' in Table 33, these are rapidly generated.

To illustrate this point we created a sub-dataset of the 816 records associated with 'Maritime Domain Awareness' (Item 4.3 in Table 32) and profiled conferences with the most papers in this area, institutions that were represented, and the names of authors who have contributed.

These profiles included in this section were created and then exported to Excel, but when viewed within the TechOASIS data files as browser sheets, the records associated with the items from all the items included in the profile are easily accessible via the Title window. This would enable immediate interactive access to the abstracts of interest.

Table 33 - Profile of top Govt/NGO's Institutions
(2003-2007 partial; 6011 records in the S&T Focus Areas subset)

Govt/NGO Institution	Publication Activity	Naval S&T Focus Areas	Unique Research
with >10 Publ. (2003-2007 par.)	**% since 2005**	**Top 5 Items**	**(Controlled Vocabulary)**
Instituto Nacional Pesquisas Espacias - INPE [174]	52% of 174	Asymetric and Irregular Warfare [49]; Operational Environments [49]; Maritime Domain Awareness [32]; Affordability, Maintainability, and Reliability [30]; Power and Energy [27]	Image sensors [14]; Orbits [9]; Charge coupled devices [8]; Fuel consumption [6]; Global positioning system [6]; Ionosphere [6]; Space research [6];
PETROBRAS [73]	45% of 73	Fleet and Force Sustainment [24]; Affordability, Maintainability, and Reliability [20]; Operational Environments [13]; Information, Analysis, and Communication [11]; Power and Energy [10]	Petroleum industry [6]; Petroleum pipelines [6]; Gas pipelines [5]; Offshore structures [5]; Marine risers [4]; Pipelines [4];
Instituto Pesquisas Energeticas e Nucleares - IPEN [61]	38% of 61	Affordability, Maintainability, and Reliability [30]; Power and Energy [14]; Operational Environments [10]; Fleet and Force Sustainment [6];	Toxicity [5]; Radiation detectors [4]; Particle detectors [3]; Zone melting [3]; Fuel cells [3];
Instituto Militar Engenharia [29]	48% of 29	Affordability, Maintainability, and Reliability [11]; Naval Warfighter Performance and Protection [5]; Power and Energy [5]; Force Projection [4];	Solid solutions [4]; Paramagnetic resonance [3]; Fading (radio) [2]; Cadmium alloys [2]; Weathering [2]; Channel capacity [2]; Differential scanning calorimetry [2];
Empresa Brasileira Pesquisa Agropecuaria - EMBRAPA [21]	43% of 21	Fleet and Force Sustainment [8]; Affordability, Maintainability, and Reliability [7]; Operational Environments [6];	Water supply [2]; Electrochemical sensors [2]; Electrodes [2]; Enzymes [2];
Comando Marinha - Brazilian Navy [20]	60% of 20	Power and Energy [6]; Affordability, Maintainability, and Reliability [4]; Asymetric and Irregular Warfare [3]; Operational Environments [3];	Wave effects [2]; Coherent light [2]; Speckle [2]; Spheres [2];
Instituto Aeronautica e Espaca - IAE [15]	47% of 15	Platform Mobility [5]; Force Projection [4]; Naval Warfighter Performance and Protection [3];	Carbon fiber reinforced plastics [2]; Flutter (aerodynamics) [2]; Epoxy resins [2]
Empresa Bras. Aeronautica - EMBRAER [13]	15% of 13	Platform Mobility [6]; Fleet and Force Sustainment [2]; Maritime Domain Awareness [2]; Force Projection [2]; Operational Environments [2]	Jet aircraft [2]; Wings [3]; Transport aircraft [2];

Table 34 - Related Conferences: "Maritime Domain Awareness"

Conference Name	**Institutions Attending** Major Contributors	**Authors** Major Contributors	**EC Class Codes**
2003 SMBO/IEEE MTT-S International Microwave and Optoelectronics Conference - IMOC 2003 [13]	Univ Fed Campina Grande [2]	Alencar, Marcelo S [2]; Queiroz, Wamberto J L [2]	741.1.2 Fiber Optics [6]; 741.3 Optical Devices & Systems [6]; 732.2 Control Instrumentation [4]; 714.2 Semiconductor Devices & Integrated Circuits [4]; 716 Electronic Equipment, Radar, Radio and Television [4]
International Joint Conference on Neural Networks, IJCNN 2005 [10]	Univ Fed Pernambuco (UFPE) [2]; Univ Fed Rio Grande Norte [2]	De Souto, Marcilio C. P [2]	723.4 Artificial Intelligence [8]; 921 Applied Mathematics [5]; 723.2 Data Processing [4]; 716.1 Information & Communication Theory [2]; 721.2 Logic Elements [2]; 716 Electronic Equipment, Radar, Radio and Television [2]
Microelectronis Technology and Devices, SBMICRO 2004 – The Nineteenth International Symposium [10]	Brasilia Univ [2]; Univ Estadual Campinas (UNICAMP) [2];	Da Costa, Jose Camargo [2]	714.2 Semiconductor Devices & Integrated Circuits [10]; 701.1 Electricity: Basic Concepts & Phenomena [5]; 723.5 Computer Applications [4]; 802.2 Chemical Reactions [4];
2004 IEEE/PES Transmission and Distribution Conference and Exposition: Latin America [10]	Desenvolvimento e Consultoria Ltda [2]; Univ Sao Paulo (USP) [2];	Dantas, Karcius Marcelus Colaco [2]; Jardini, Jose Antonio [2]; Alencar de Souza, Benemar [2]; Neves, Washington Luiz Araujo [2];	706.1 Electric Power Systems [6]; 701.1 Electricity: Basic Concepts & Phenomena [5]; 723.4 Artificial Intelligence [4]; 731.1 Control Systems [4]; 704 Electric Components and Equipment [3]

Ideas for Further Exploration

The approach used for identifying defense-related R&D admits that a significant amount of human intervention is required by a single analyst (with no special expertise in defense technologies). Some of our other explorations sought a more highly algorithmic approach, but these have not yet borne fruit.

A query-based approach would be one possible alternative. In this model we would put to use all applicable tools available from the source database. The EC database, for example, has a classification code assigned for 'Military Engineering'. Classification Codes, Controlled Vocabulary terms, and key content terms such as 'body armor' could be built into a search query targeted to retrieve records related to core defense technologies. A major drawback of this approach, however, is that the query itself may not be easily translated across database platforms. Furthermore, the potential for knowledge discovery is limited when your query returns only core defense S&T literature. That is, outreach to related topics could be more valuable in treating the open literature.

An objective (automatable) approach to identifying the defense-related literature would be preferable to the human-driven processes because it:

1. Will be much faster
2. Can be applied to a small or large sample of records for a particular S&T discipline (i.e. for identifying interesting defense-related Nanotechnology publications)
3. Parameters of an algorithmic approach could be loosened to find more 'fringe' research (i.e. with indirect defense ties), or tightened to retrieve core literature.

We see potential in further exploration of ways to elicit intelligence concerning defense-relevant R&D literature. The scope of this project limited what we could try.

9. Discussion

Substantive Findings

Brazil has the largest Latin American R&D enterprise, supported and conducted by a mix of governmental and private sector institutions. Most of its substantial research publication (~18,000 articles in internationally indexed journals in the Science and Social Science Citation Indexes in 2006) emanates from academia, which employs 90% of the country's 48,000 S&T PhD's. And it is growing – up 64% from SCI/SSCI publications (2000).

This enterprise has notable strength in the life and biomedical fields, and substantial strength as well in the physical sciences. Brazil shows relative strength compared to the USA particularly in agriculture, physics, chemistry, and materials sciences.

International collaboration is extensive – 5,446 of 17,965 Brazilian papers in SCI/SSCI (43.5%). The USA is the leading collaborator – 2,049 of those papers. Thus, there is a strong base of existing joint research experience on which to build.

We identify an elite tier of leading academic and governmental research organizations, led by the University of Sao Paulo (with 2.5 times as many publications as any other organization – 4,472 in 2006).

Country Study Process Observations and Suggestions

We sought to compare Brazil's R&D funding with its research publication concentrations. Unfortunately these do not align in a satisfactory way to yield credible comparisons. Note how diverse the breakouts of governmental support in Tables 1 and 2 are, no less the tallies of industrial R&D investment (Table 3). Nonetheless, such comparisons are of interest and ought to be explored in future country studies. In other studies we have found striking differences between academic research emphases and national industrial emphases (e.g., for Malaysia – Newman et al., 1997).

SCI/SSCI and EC provide complementary slices of a nation's research enterprise outputs. INSPEC might further round out coverage of Science & Technology areas. Exploration of patenting (e.g., via Derwent World Patent Index through the Web of Knowledge site used for SCI/SSCI) could prove informative on the extent to which R&D is effectively exploited to promote technological innovation for commercial and/or defense purposes.

This and other country studies provide multiple windows on a nation's research enterprise – applying a range of categorizations, tabulations, and network maps. We think this is a strength – offering multiple perspectives.

Taxonomic profiling provides an inductive map of a nation's research endeavors unconstrained by prior deductive categories. We find the SCI/SSCI taxonomy more helpful than that derived from EC records. However, we believe that EC's class codes and controlled vocabulary

keywords are potentially more fruitful to explore defense-oriented R&D – particularly in an interactive mode.

We are especially enthused about the prospects for *interactive* country studies. Reports such as this do a good job of presenting the "research landscape" generally. However, to answer one's particular questions about "who is doing what?" interactive data access can multiply the utility many times over. Section 7 indicates how two desktop software tools, SpaceTree and TechOASIS, can provide convenient, hands-on access to this research intelligence. We are also glad to respond to specific inquiries. For instance, we can readily profile particular organizations and/or particular S&T topics to identify leading individual researchers on a topic, how current their research is, and recent American collaborators.

This study also explored identifying military-relevant R&D from open literature compilations. Straightforward searching for papers authored by researchers with military affiliations or acknowledging military funding support provides a start. More interesting as a potential exploratory mechanism is examination of second-order links. In terms of "who?" one could profile the other outputs of researchers or research centers that collaborate with defense colleagues on some studies. Here we briefly discussed searching topical identifiers (e.g., keywords and title phrases) that suggest direct or secondary association with particular Naval research thematic interests ("what?"). One could pursue this further by examining the "who & what" together – e.g., which organizations are prominently pursuing particular topics of potential military interest? And, obviously, one could profile R&D activities in such a way to pursue non-military interests as well.

This study has drawn on persons knowledgeable about Brazilian R&D in summarizing the country's research funding structure and in formulating the analyses. However, were one pursuing the present empirical results, we would strongly endorse engaging topical subject and Brazilian innovation process experts to interpret and extend this research profile.

Brief comparisons with the research of other American hemisphere countries [Argentina, Canada, Chile, and Mexico (country study available)] suggest potential value in exploring our neighbors' research enterprise via corresponding country studies. It would be informative to hear from users of prior country studies just which "research intelligence" was most valuable and what additional information they would like.

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Appendices

Data for Figure 5 - Brazilian Publications for 3 High Impact Factor Journals

Year	Summary			JACS			Phys. Rev. Lett.			J. Biol Chem		
	India	China	Brazil	Brazil	India	China	Brazil	India	China	Brazil	India	China
1995	48	18	39	2	5	2	11	34	14	26	9	2
1996	79	40	57	0	17	5	19	49	33	38	13	2
1997	86	49	64	4	17	11	12	52	31	48	17	7
1998	99	75	73	3	23	12	14	66	56	56	10	7
1999	85	68	63	3	11	13	20	51	39	40	23	16
2000	90	130	89	6	19	35	27	54	70	56	17	25
2001	116	180	106	2	15	49	30	59	85	74	42	46
2002	94	183	107	7	14	45	37	49	82	63	31	56
2003	134	306	112	11	19	89	31	55	134	70	60	83
2004	119	360	101	6	15	99	32	50	151	63	54	110
2005	123	424	118	10	27	142	26	52	158	82	44	124

Key
JACS=Journal of the American Chemical Society
Phys. Rev. Lett. =Physical Review Letters
J Biol Chem =Journal of Biological Chemistry

Figure 28 - China SCI Taxonomy - 35000 Records 2004-2005

<table>
<tr><th>LEVEL 1</th><th>LEVEL 2</th><th>LEVEL 3</th><th>LEVEL 4</th></tr>
<tr><td rowspan="6">physical and materials sciences (16030)</td><td rowspan="3">chemistry, molecular structure (7693)</td><td rowspan="2">chemical reactions, catalysis (5212)</td><td>analytical chemistry methods, spectral analyses (3277)</td></tr>
<tr><td>catalytic reactions (1935)</td></tr>
<tr><td colspan="2">crystal and chemical structure, synthesis (2481)</td></tr>
<tr><td rowspan="3">materials and structural properties, thin films, ceramics (8337)</td><td rowspan="2">performance of metals, alloys, composites, ceramics (6564)</td><td>powders, microcrystalline materials, crystal growth, materials preparation (3748)</td></tr>
<tr><td>metal alloys, ceramics (2816)</td></tr>
<tr><td colspan="2">thin film preparation, properties, and applications (1773)</td></tr>
<tr><td rowspan="7">life sciences, mathematics (18969)</td><td rowspan="3">numerical modeling and simulation (11607)</td><td rowspan="2">mathematical and numerical methods, theoretical equations and models (6957)</td><td>modeling of systems and phenomena (4871)</td></tr>
<tr><td>mathematical theory and application (2086)</td></tr>
<tr><td colspan="2">computational processing techniques, networks, information processing (4650)</td></tr>
<tr><td rowspan="4">Biology and medicine (7362)</td><td rowspan="2">health research, disease treatment, plant and environmental science (3649)</td><td>soils, plants, geoscience (2023)</td></tr>
<tr><td>clinical treatment of diseases, occupational health, cancer research and treatment (1626)</td></tr>
<tr><td rowspan="2">biochemistry and molecular biology, gene expression, pharmacology (3713)</td><td>gene expression and sequencing (1473)</td></tr>
<tr><td>cell expression, pharmacology (7362)</td></tr>
</table>

Figure 29 - India SCI Taxonomy 2005; 15000 Records

(5513) BIOMEDICAL; ENVIRON	(2626) BIOLOGICAL RESEARCH	(1458) ANIMAL EXPERIMENTS/ PLANT BIOLOGY	(807) PLANT BIOLOGY
			(651) ANIMAL EXPERIMENTS
		(1168) CELL BIOLOGY/ GENETICS	
	(2887) CLINICAL MEDICINE; ENVIRON	(1218) HUMAN PATIENT DISEASES	
		(1669) GEOLOGICAL/ MAT'L MECHANICS/ AGRICULTURAL RES	(952) SOIL/ CROP EXPERIMENTS
			(717) GEOLOGICAL RES/ MATERIAL MECHANICS
(8795) PHYSICAL SCIENCES/ MATHEMATIC	(3691) MATHEMATIC	(1372) ALGORITHMS/ NETWORK MODELING	
		(2319) MATH ANALYSIS	(1255) CONTINUUM ANALYSIS
			(1064) MOLEC LEVEL CALC
	(5104) PHYSICAL SCIENCES	(2867) SURF PHYS/ CHEM	(1576) FILM PHYS
			(1291) FILM CHEM
		(2237) COMPOUND CHEMISTRY	(939) CHEM BOND/ CRYS STRUCT
			(1298) REACT/ CATAL/ SYNTH

Figure 30 - China EC Taxonomy for years 2000-2003

LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
(9949) - Physical and Computer Sciences [100%]	(4721) - Computer Sciences [47%]	(3902) - Cybernetics & Systems Engineering [39%]	(3178) - Power & Systems Engineering [31.9%]	(852) - Power/Energy Market Enterprises [8.6%]
				(2326) - Systems Theory [23.4%]
			(724) - Networks & algorithms (neural, comms, mobile, wireless, genetic) [7.3%]	(387) - networks -- neural, communications, mobile, wireless [3.9%]
				(337) - algorithms - genetic, (adaptable, learning, smart) [3.4%]
		(819) - Signal Processing (image, digital, wavelets) [8%]	(511) - Image Processing (detection & embedding) [recognition, matching, retrieval, segmentation] [5.1%]	(339) - image processing (reconstruction, matching, retrieval, & segmentation) [for similarities] [3.4%]
				(172) - image processing and watermarks (detecting & embedding) [for differences] [1.7%]
			(308) - Signal Processing (wavelets & digital signal processing) [3.1%]	(182) - wavelets in imaging & non-imaging signals [1.8%]
				(126) - digital signal processing to extract signals [1.3%]
	(5228) - Physical Sciences [sub-systems] [53%]	(3477) - Materials Science & Mathematics [35%]	(474) - Mathematics (Solutions & Equations) [4.8%]	(209) - Solutions (Periodic & Non-periodic) [2.1%]
				(265) - Equations [2.7%]
			(3003) - Physics of Structural Mechanics & Materials [30.2%]	(921) - Applied Measurements (with Optics & Lasers) [9.3%]
				(2082) - Structural Mechanics & Materials [20.1%]
		(1751) - Chemistry & Nanotechnology [18%]	(747) - Nano-technology (Nano-structures & Materials) [7.5%]	(285) - Nanostructures [2.9%]
				(462) - Crystals, Glass, Lasers, Plasmas, and Magnetic & Piezoelectric Compounds [4.9%]
			(1004) - Chemistry (Organic & Inorganic) [10.1%]	(285) - Inorganic Chemistry (Solid & Liquid Material Dopping) [2.9%]
				(719) - Organic Chemistry [7.2%]

Table 35 - Population of Selected Countries[a]
(July 2007, est.)

Brazil	190,010,647
South Korea	49,044,790
Mexico	108,700,891
Chile	16,284,741
Canada	33,390,141
Argentina	40,301,927

Table 36 - Comparison of GDP, Selected Countries[a]

	Brazil	**S. Korea**	**Mexico**	**Chile**	**Canada**	**Argentina**
Purchasing Power Parity:	$1.655 T	$1.196 T	$1.149 T	$202.7 B	$1.178 T	$608.8 B
Official Exchange Rate:	$967 B	$897.4 B	$743.5 B	$111.8 B	$1.088 T	$210 B
Per Capita (PPP):	$8,800	$24,500	$10,700	$12,700	$35,600	$15,200
Real Growth Rate:	3.70%	4.80%	4.80%	4.20%	2.70%	8.50%
Composition by Sector:						
- Agriculture:	8%	3%	3.9%	5.9%	2.3%	9.5% *****
- Industry:	38%	45%	25.7%	49.3%	29.2%	35.8% *****
- Services:	54%	52%	70.5%	44.7%	68.5%	54.7% *****
Military exp. (% GDP):	2.6%	2.7%	0.5%	2.7%	1.1% *****	1.3% *****

Note: GDP Figures reflect 2006 (estimated.) unless otherwise indicated by *****

[a] Data from the *CIA World Factbook*, as of August 20, 2007: https://www.cia.gov/library/publications/the-world-factbook/

Terms for Identifying Defense-Related R&D

"Objectives" copied from *Naval S&T Strategic Plan* (ONR, 2007), Sections 4.1 through 4.13. "Associated CV Terms" are related terms found within the Brazil EC sample of 21753 records from 2003-2007 (partial).

4.1 Power and Energy

Objectives

- Alternative Energy Sources
- Use of synthetic hydrocarbons and alternative fuels
- Wave action and bio-energy conversion
- Energy Storage
- Portable, rechargeable, and reserve batteries
- Personal power
- Efficient Energy and Power Conversion
- Materials to increase efficiency and power density
- Power distribution architectures
- Motors and actuators
- Technologies in lubrication, friction, and wear
- High Energy and Pulse Power
- Energy storage power system architectures
- Energy pulsed power switching and control systems

Associated CV Terms

Fuel (all variants)
Energy (all variants)
Power (all variants)
Asynchronous generators
Catalyst regeneration
Charging (batteries)
Cogeneration plants
DC generator motors
DC generators
Electric batteries
Electric generators
Hydroelectric generators
Lead acid batteries
Lithium batteries
Nickel cadmium batteries
Nuclear batteries
Primary batteries
Regenerators
Secondary batteries
Turbogenerators

4.2 Operational Environments

Objectives

- Mobile autonomous environmental sensing:
- Autonomous sensing of ocean and littorals to beach exit zone
- Actionable environmental sensing that automatically adapts sensing strategy to
- changing conditions
- Match predictive capabilities to tactical planning requirements:
- Coupled ocean-atmosphere global, regional, and local modeling and prediction for operational planning
- Forecasts for refractivity, duct heights, fog, rain, clouds, visibility, tropical cyclones at global, regional and tactical scales to increase mission planning and success
- Adapt Systems to the Environment:

- Methods to account for acoustic and electromagnetic propagation, scattering, ambient noise, and bottom effects
- Automated sensor and weapon performance prediction and reconfiguration
- Impact and response for space environmental effects

Associated CV Terms

Amperometric sensors
Carrier sense multiple access
Chemical sensors
Context sensitive languages
Detectors
Dissolved oxygen sensors
Edge detection
Electrochemical sensors
Error detection
Fiber optic sensors
Hybrid sensors
Image sensors
Infrared detectors
Leak detection
Obstacle detectors
Optical sensors
Oxygen sensors
Particle detectors
Potentiometric sensors
Proximity sensors
Radiation detectors
Remote sensing
Sensitivity analysis
Sensitometers
Sensor data fusion
Sensors
Sensory perception
Signal detection
Ultraviolet detectors

4.3 Maritime Domain Awareness

Objectives

- Sensor integration
- Rapid, accurate, multi-source data integration
- Automated integration of national and tactical sensors
- Data fusion to adapt non-organic and sparse information
- Pervasive and persistent sensors
- All domain coverage (space, air, surface, and sub-surface)
- Affordability vs. endurance and reliability trade off
- Fully automated (self-networking with sensor-level processing)
- Secure and taskable data exfiltration nodes
- Tactical sensor networks
- Autonomously interconnecting with real-time monitoring
- Secure, survivable, self-healing, and adaptable
- Resistant to jamming
- Homeland and port defense monitoring
- New systems and protocols for target identification and tracking using fixed and deployable cueing systems
- WMD detection tools
- Combat ID
- Rugged identification technologies

Associated CV Terms

Application specific integrated circuits
Computer integrated manufacturing
Condition monitoring
Identification (control systems)
Image sensors
Integrated circuits
Integrated control
Integrated optics
Interconnection networks
Monitoring
Neural networks
Optical sensors
Proximity sensors
Radial basis function networks
Security systems
Sensor data fusion
Sensors

4.4 Asymmetric and Irregular Warfare

Objectives

- ISR
- Unmanned vehicles: intelligent autonomous unmanned vehicles, sensors,and communications
- Interior and exterior imaging: rapidly reconstruct and fuse multi-aspect sensor data into 3-D tactical models of building interiors and exteriors
- Riverine surveillance: common and persistent maritime picture on and below the surface and shore
- Intelligence Analysis
- Image and pattern recognition tools
- Societal, cultural, and behavioral modeling
- Biometrics
- Active and Passive Forensics Tools
- Field-portable forensic tools, sensors, and sensor networks, as well as spectrally-coded particulate markers and probes
- Advanced Countermeasures
- Dominate the electromagnetic spectrum
- Predict, detect and neutralize IEDs and P-IEDs
- Deny adversaries the ability to hide within the civilian population
- Phase 0 S&T in support of combatant commander's (COCOM) engagement plan
- Electronic camouflage

Associated CV Terms

Acoustic imaging
Artificial intelligence
Autonomous agents
Biomechanics
Color image processing
Digital image storage
Geological surveys
Hydrographic surveys
Image analysis
Image coding
Image communication systems
Image converters
Image enhancement
Image processing
Image quality
Image reconstruction
Image retrieval
Image sensors
Imaging systems
Imaging techniques
Intelligent agents
Intelligent control
Intelligent materials
Intelligent networks
Intelligent robots
Intelligent structures
Optical image storage
Plasma probes
Probes
Radar imaging
Space probes
Space surveillance
Speech analysis
Speech coding
Speech communication
Speech intelligibility
Speech processing
Speech recognition
Speech synthesis
Speech transmission
Speech
Surveillance radar
Surveying
Thermography (imaging)
Ultrasonic imaging
Underwater imaging
Unmanned vehicles

4.5 Information, Analysis, and Communication

Objectives

- Rapid, Accurate, Decision-Making
- Enhanced human decision-making while reducing the time-filtering of data and information
- Automated generation and management of courses of action

- Automated graphical representation of commander's intent
- Knowledge and task focused human-system interfaces
- Information assurance (authenticity, accessibility, and validity)
- Decision aids
- Smart algorithm development for optimal action
- Networked architecture for real-time operations
- Rapid and reliable data access for threat-intent determination
- Communications and Networks
- Mobile ad hoc networking
- On-demand systems reach back
- Quality-of-service mechanisms for commander's Intent
- Autonomous monitoring and control of tactical communications and networks
- Automatic alignment of sensors and networks
- Cyber Warfare
- Cyber security and information assurance
- Information operations

Associated CV Terms

Condition monitoring
Cybernetics
Decision feedback equalizers
Decision making
Decision support systems
Decision tables
Decision theory
Knowledge acquisition
Knowledge based systems
Knowledge engineering
Knowledge representation
Monitoring
Real time systems

4.6 Power Projection

Objectives

- Future Navy Fires
- Increased volume and accuracy
- GPS-denial compensation
- Indirect fires to 250 miles from safe offshore locations
- Control Collateral Damage
- Scalable-effects weapons
- Selectable or directional lethality
- Time Critical Strike
- Hardened target and moving target reach and destroy
- Worldwide strike capability to meet warfighter requirements
- Small Unit Combat Power
- Increased small unit weapon lethality
- Neutralize larger hostile forces
- Combat Insensitive Munitions
- Reduce system sensitivity to sympathetic detonation
- Maintain payload range and lethality

Associated CV Terms

Ballistics
Blasting
Boosters (rocket)
Explosion testing
Explosions
Explosives
Flight dynamics
Guns (armament)
Impact testing

Launching
Military aircraft
Military applications
Military satellites
Military vehicles
Missiles
Motion compensation
Motion control
Motion estimation
Nuclear explosions
Plasma guns
Projectiles
Rocket engines
Rockets
Sounding rockets
Submarines
Submersibles
Torpedoes
Underwater explosions

4.7 Assure Access and Hold at Risk

Objectives

- Anti-Submarine and Mine Warfare
- Rapid clearing and detection of mines
- Advanced autonomy in unmanned robotic systems to expand ground reach and reduce threat exposure
- Next-generation data and contact fusion to expand the regional antisubmarine, mine and amphibious warfare operating picture to the theater level
- Distributed Surveillance
- Distributed, networked surface, ground, and underwater sensors
- Unmanned systems with onboard processing
- Autonomous maritime reconnaissance and neutralization
- Battlespace Shaping
- Non-lethal technologies to stop small vehicles and large ships
- Battlespace shaping technology for enabling information operations
- Decisive operations through a heavy electronic warfare (EW) attack area
- Access to GPS-denied areas–alternatives to GPS technology
- Operationally responsive use of space
- Tagging, tracking, and locating technologies

Associated CV Terms

Detectors
Dynamic positioning
Edge detection
Error detection
Fiber optic sensors
Global positioning system
Hybrid sensors
Image sensors
Infrared detectors
Obstacle detectors
Optical sensors
Position control
Position measurement
Proximity sensors
Pulse position modulation
Radar tracking
Sensor data fusion
Sensory perception
Signal detection
Tracking (position)
Ultraviolet detectors
Unmanned vehicles

4.8 Distributed Operations

Objectives

- Training
- Enhancement of physical and cognitive performance
- Simulation based scenarios for enhanced training
- Rapid assimilation of cultural environments
- Communications
- Robust command and control networks

- Airborne relays on manned and unmanned platforms
- Logistics
- Rapid re-supply and medical evacuation whenever possible
- Real time automatic supply sensors and network
- Optimize medical self-sufficiency
- Fires
- Integrate firepower of distributed ground, offshore, and air assets
- Blue force tracking down to the individual
- Survivability
- Warfighter stealth technology
- Warfighter exoskeleton technology
- Maneuver
- Adaptable and survivable tactical mobility systems to enhance operational tempo and extend range of vehicles and soldiers
- Advanced materials to reduce combat load

Associated CV Terms

Active networks
Data communication equipment
Data communication systems
Distributed parameter control systems
Emergency vehicles
Global positioning system
Global system for mobile communications
Intelligent networks
Military satellites
Mobile telecommunication systems
Radio communication
Real time systems
Satellite communication systems
Strategic materials
Telecommunication equipment
Telecommunication systems
Virtual reality
Wireless telecommunication systems

4.9 Naval Warfighter Performance and Protection

Objectives

- Training and Education
- Technologies to shorten training time and maximize training impact
- Computational models of human cognition applicable to tactical operations
- Advanced decision tools for conclusive action in all operational environments
- Risk and uncertainty in complex combat scenarios
- Casualty Care and Prevention
- Understand combat physiological and mental stressors
- Improve warfighter resilience in the full range of military environments and health threats
- Warfighter Protection
- Advanced materials for lighter body armor
- Advanced materials for lighter equipment
- Manpower management
- Human factors and organizational design to assist in resource management

Associated CV Terms

Armor
Carbon fiber reinforced plastics
Distance education
Education computing
Education
Fiber reinforced materials
Fiber reinforced plastics
Fire protection

Loss prevention
Medical education
Medical problems
Medicine
Nuclear materials safeguards
Personnel training
Protection
Radiation protection
Risk management
Safety devices
Safety factor
Safety valves
Telemedicine

4.10 Survivability and Self-Defense

Objectives

- Platform Stealth
- Reduce above-water and subsurface signatures
- Multi-spectral low observable (LO) technologies
- Countermeasures & Counterweapons
- Threat weapon tracking
- Automated decision making
- Low-false-alarm-rate, 360-degree detection
- Hard kill and soft kill against threat kinetic weapons
- Increase standoff to outside threat damage range
- Directed energy weapons for speed of light engagement
- Counter-LO
- Survivable Platforms
- Advanced materials in platform construction
- Damage tolerant platform architectures
- Automated damage control focusing
- Advanced materials for self-healing platforms
- Force Protection
- Anti-swimmer technology
- Detect and determine threat intent
- Non-lethal response

Associated CV Terms

Block codes
Cryptography
Decoding
Doppler radar
Encoding (symbols)
Ground penetrating radar systems
Meteorological radar
Multispectral scanners
Optical radar
Quantum cryptography
Radar antennas
Radar clutter
Radar cross section
Radar imaging
Radar measurement
Radar target recognition
Radar tracking
Radar
Signal encoding
Spread spectrum communication
Strength of materials
Surveillance radar
Synthetic aperture radar
Trellis codes
Turbo codes
Vocoders

4.11 Platform Mobility

Objectives

- Efficient, high-endurance, high-speed platforms
- New and novel advanced platform design supporting new directions in Naval warfare (size, agility, modularity, etc.)

- Higher performance at reduced fuel consumption aerodynamic and hydrodynamic propulsion and power plants
- All-terrain, lighter, more agile ground vehicle suspensions and drive trains
- Manned or unmanned surface vessel launch and recovery
- Lightweight and higher strength advanced composites and structural metals (cellular, lightweight alloys) building blocks
- Vertical lift operations in challenging environments
- High performance vertical takeoff and landing/vertical-short takeoff and landing (VTOL/VSTOL)
- High sea states launch-and-recovery technology to enable manned or unmanned air and surface platform operations
- Autonomous and unmanned vehicle mobility
- Vehicle design technology for littoral missions and environments
- Multi-unmanned vehicles supporting simultaneous cooperative operations
- Advanced robotic systems for ground combat

Associated CV Terms

AC motors
Aerodynamic heating
Aerodynamic loads
Aerodynamics
Aircraft engines
Automobile engine manifolds
Automobile engines
Boosters (rocket)
Computational fluid dynamics
DC generator motors
DC motors
Diesel engines
Drag
Engine cylinders
Exhaust systems (engine)
Flow of fluids
Fluid dynamics
Fluidics
Fluidity
Flutter (aerodynamics)
Fractional horsepower motors
Gas engines
Hypersonic aerodynamics
Induction motors
Internal combustion engines
Internal friction
Linear motors
Marine engines
Motor transportation
Motors
Propellants
Propulsion
Reluctance motors
Rocket engines
Rockets
Rotary engines
Shaftless motors
Ship propellers
Solid propellants
Sounding rockets
Spacecraft propulsion
Speed control
Squirrel cage motors
Stepping motors
Supersonic aerodynamics
Synchronous motors
Traction (friction)
Transonic aerodynamics
Turboprop engines
Viscosity of gases
Viscosity of liquids
Wind tunnels

4.12 Fleet and Force Sustainment

Objectives

- Sea Basing
- Seabased logistics and communications operations modeling and simulation
- Ship-to-ship and ship-to-shore logistics
- Heavy-lift vehicle launch and recovery
- Flexible and responsive warehousing
- Responsive and Visible Logistics
- Point-of-delivery systems
- Total asset visibility technologies
- Flexible and responsive logistics
- Autonomous Re-supply

- Intelligent re-supply agent systems
- Sense and respond delivery system

Associated CV Terms

Air transportation
Airports
Biological water treatment
Cables
Cargo handling
Color removal (water treatment)
Controllability
Cranes
Decentralized control
Efficiency
Energy resources
Food additives
Food preservation
Food preservatives
Food processing
Food products plants
Food products
Food storage
Force control
Freight transportation
Fuel storage
Gas fuel storage
Gas supply
Hydrogen sulfide removal (water treatment)
Industrial engineering
Industrial management
Industrial water treatment
Intelligent control
Lead removal (water treatment)
Maintenance
Management science
Marine engineering
Marine risers
Motor transportation
Multivariable control systems
Natural gas transportation
Natural resources
Offshore structures
Petroleum transportation
Pneumatic control
Pneumatic conveyors
Portable equipment
Ports and harbors
Potable water
Predictive control systems
Preventive maintenance
Remote control
Renewable energy resources
Resource valuation
Sediment transport
Storage (materials)
Transport aircraft
Transportation charges
Transportation routes
Warehouses
Waste management
Wastewater treatment
Water analysis
Water filtration
Water pipelines
Water resources
Water supply systems
Water supply
Water tanks
Water treatment
Waterway transportation

4.13 Affordability, Maintainability, and Reliability

Objectives

- Platform Affordability
- Advanced modeling and simulation for design, test and evaluation
- Advanced composite alloys and ceramics
- Open architecture for hardware

- Software reliability
- Low-cost sensors
- Innovative manufacturing technologies
- Maintenance and Lifecycle Cost
- Condition-based maintenance systems
- Corrosion control technology
- Wear resistant life-time materials
- Energy efficient systems
- Performance prediction modeling and simulation tools
- Automation to Reduce Manning
- Small autonomous vehicles and systems
- Operator action reduction technologies
- Remote monitoring (diagnostics and correction)
- Automated control systems

Associated CV Terms

Alloys (and all variants)
Atmospheric corrosion
Automata theory
Automation
Ceramic coatings
Ceramic fibers
Ceramic foams
Ceramic materials
Ceramic matrix composites
Ceramic products
Ceramic tools
Corrosion inhibitors
Corrosion protection
Corrosion resistance
Corrosive effects
Cost accounting
Cost benefit analysis
Cost effectiveness
Costs
Durability
Ferroelectric ceramics
Glass ceramics
Life cycle
Maintainability
Maintenance
Management science
Marine applications
Reliability theory
Reliability
Strategic planning
Structural ceramics
Sustainable development
Underground corrosion
Wear of materials
Wear resistance